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State of Connecticut.
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SEVENTEENTH ANNUAL REPORT

OF THE

STORRS

AGRICULTURAL EXPERIMENT STATION,

STORRS, CONN.

FOR THE YEAR ENDING JUNE 30, 1905.

PRINTED BY ORDER OF THE LEGISLATURE

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PUBLICATION

APPROVED BY

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OF THE

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Publications of the Station

AVAILABLE FOR FREE DISTRIBUTION.

THE STORRS AGRICULTURAL EXPERIMENT STATION is located in Mansfield Township, Tolland County, Connecticut, and is under the control of the Board of Trustees of the Connecticut Agricultural College. The freight and express station is Eagleville, Conn., on the Central Vermont Railroad. The telegraph address is Willimantic, with which city the Station is connected by telephone. Long distance telephone connection brings all points of the State into direct communication with the Station.

The following publications of the Storrs Agricultural Experiment Station are available for distribution, and, as long as the supply lasts, will be sent free to all who desire them.

All correspondence should be addressed to

STORRS AGRICULTURAL EXPERIMENT STATION,

STORRS, CONNECTICUT.

BULLETINS.

No. 5. Atmospheric Nitrogen as Plant Food.
No. 7. Chemistry and Economy of Food.
No. 12. The Ripening of Cream by Artificial Bacteria Cultures.
No. 14. The Elm Leaf Beetle.
No. 20. A Study of Dairy Cows.
No. 21. The Ripening of Cream.
No. 23. The Relation of Bovine Tuberculosis to that of Man and its Significance in the Dairy Herd.
No. 25. The Covered Pail a Factor in Sanitary Milk Production.
No. 26. The Relation of Temperature to the Keeping Property of Milk.
No. 27. Poultry as Food.
No. 28. Dairy Observations.
No. 29. Records of a Dairy Herd for Five Years.
No. 30. Spraying Notes for 1903.
No. 31. Food Value of a Pound of Milk Solids.
No. 32. Protecting Cows from Flies.
No. 33. A Successful Brooder House.

No. 34. Discussion of the Amount of Protein Required in the Ration for Dairy Cows.
No. 35. The Camembert Type of Soft Cheese in the United States.
No. 36. Poultry Suggestions for the Amateur.
No. 37. The So-called "Germicidal Property" of Milk.
No. 38. The Marketing of Poultry Products.
No. 39. Pig Feeding Experiments.
No. 40. Creamery Problems.
No. 41. Spraying Notes, 1904–1905.
No. 42. Quality of Milk Affected by Common Dairy Practices.

REPORTS.

The Reports of the Storrs Agricultural Experiment Station for 1889, '90, '91, '94 (Part III.), '95 (Part III.), '96 (Part II.), '98, '99, 1900, 1901, 1902–3, 1904, 1905, are available for free distribution.

Address all requests to the Director of Storrs Agricultural Experiment Station, Storrs, Conn.

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Report of the Treasurer

For the Fiscal Year Ending June 30th, 1905.

The following summary of receipts and expenditures, made out in accordance with the form recommended by the United States Department of Agriculture, includes, first, the Government appropriation of $7,500, and, secondly, the annual appropriation of $1,800 made by the State of Connecticut, together with various supplemental receipts. These accounts have been duly audited according to law, as is shown by the Auditors' certificates, copies of which are appended.

GOVERNMENT APPROPRIATION—RECEIPTS AND EXPENDITURES

RECEIPTS	
United States Treasury,	$7,500 00
EXPENDITURES	
Salaries,	$3,544 14
Labor,	1,528 73
Publications,	192 10
Postage and stationery,	164 03
Freight and express,	68 87
Heat, light, water, and power,	84 96
Chemical supplies,	177 65
Seeds, plants, and sundry supplies,	452 49
Feeding stuffs,	314 24
Library,	65 22
Tools, implements, and machinery,	29 74
Furniture and fixtures,	82 00
Scientific apparatus,	21 76
Live stock,	59 50
Traveling expenses,	456 89
Contingent expenses,	15 00
Buildings and repairs,	242 68
	$7,500 00

AUDITORS' CERTIFICATE

We, the undersigned, duly appointed Auditors of the Corporation, do hereby certify that we have examined the books and accounts of the Storrs Agricultural Experiment Station for the fiscal year ending June 30, 1905, that we have found the same well kept and classified as above, and that the receipts for the year from the Treasurer of the United States are shown to have been $7,500 and the corresponding disbursements $7,500, for all of which proper vouchers are on file and have been examined by us and found correct, thus leaving no balance.

And we further certify that the expenditures have been solely for the purposes set forth in the act of Congress approved March 2, 1887.

(Signed) Geo. A. Hopson, A. J. Pierpont, } *Auditors*

Storrs, Conn., July 15, 1905.

STATE APPROPRIATION AND SUPPLEMENTAL RECEIPTS

RECEIPTS AND EXPENDITURES

RECEIPTS

State of Connecticut,	$1,800 00
Miscellaneous receipts,	684 31
	$2,484 31

EXPENDITURES

Salaries,	$1,246 89
Labor,	139 79
Postage and stationery,	32 26
Freight and express,	50
Chemical supplies,	48 74
Seeds, plants, and sundry supplies,	278 15
Feeding stuffs,	36 80
Scientific apparatus,	58 50
Live Stock,	289 84
Traveling expenses,	33 89
Balance,	318 95
	$2,484 31

AUDITORS' CERTIFICATE

We, the undersigned, duly appointed Auditors of the Corporation, do hereby certify that we have examined the books and accounts of the Storrs Agricultural Experiment Station for the fiscal year ending June 30, 1905, that we have found the same well kept and classified as above, and that the receipts for the year from the State of Connecticut are shown to have been $1,800, and the receipts from miscellaneous sources $684.31, making the total receipts from the State and miscellaneous sources $2,484.31. The corresponding disbursements were $2,165.36, for all of which proper vouchers are on file and have been by us examined and found to be correct, thus leaving a balance of $318.95.

(Signed) GEO. A. HOPSON, A. J. PIERPONT, } *Auditors*

STORRS, CONN., July 15, 1905.

E. O. SMITH, *Treasurer.*

Report of the Director.

During the past year the work of the Storrs Agricultural Experiment Station has proceeded along the same general lines as outlined in the report for the year ending June 30, 1904. There have been no radical changes in the policy of the Station and but few in the lines of the work taken up. We believe that as a matter of Station policy it is well to confine our experiments to a few definite lines, and in these lines to do thorough work until we have completed the investigations.

CHANGES IN THE STATION STAFF.

We have been especially fortunate during the past year in that we have not been compelled to make many changes in the working staff. Professor F. H. Stoneburn resigned his position as poultryman in College and Station, and the position has been filled by the appointment of Professor C. K. Graham.

Mr. A. W. Bosworth, who was engaged by the Department of Agriculture in our coöperative cheese investigations, resigned his position as chemist and has been succeeded by Mr. Arthur W. Dox.

COÖPERATION WITH THE U. S. DEPARTMENT OF AGRICULTURE.

Our work in coöperation with the United States Department of Agriculture has continued satisfactorily during the year. The special problems in the investigation of the manufacture of soft cheese are so difficult in their nature that some time certainly must elapse before we are able to reach definite conclusions. Consequently the progress of this work will be apparently slow. In spite of this fact definite advance has been made during the year. A preliminary bulletin has been published upon the subject of "The Camembert Type of Soft Cheese in the United States," and other bulletins on the same general subject are in course of preparation.

We have found that some of the varieties of soft cheese which are popular in this country as well as in Europe can be successfully manufactured here. The Camembert cheese which we have made has been pronounced by experts equal to the best European product in every way.

One factory has introduced the making of Camembert cheese as a result of our experiments in this line. Their cheese maker came here and spent several weeks in getting familiar with the details of manufacture, and they are now producing a first-class article, which is finding ready sale in the markets.

The next type of cheese which will receive attention is the Roquefort. There seems to be for this an even greater demand than for the Camembert type, and if, as a result of our experiments we make it possible to manufacture a good quality of Roquefort in America, it will certainly be a work which should bring credit to the Station and to the state.

The part of the state fund which has heretofore been used in the food nutrition investigations is now being used to conduct experiments in the manufacture of soft cheese.

POULTRY INVESTIGATIONS.

Under the direction of Professor C. K. Graham, the poultry experiments have been increased, and at the present time much interesting work is in progress. There is no department of our work which seems to appeal more directly to the general public than does our poultry investigation. Many who are interested in no other line of agriculture take special interest in poultry. The poultry bulletins which have been issued during the past year have been in great demand. Other bulletins will be issued during the coming year giving results of experiments in poultry work.

The experiments with squabs have been continued now for more than two years, and during the coming year these experiments may be concluded. Important data have been secured, and it seems unwise to expend further effort in this direction.

DAIRY HUSBANDRY.

Experiments along dairy lines have been in progress during the entire year, and the bulletins issued by this department are in wide demand. Bulletin No. 31, entitled "The Food Value

of a Pound of Milk Solids,'' has been issued in a special edition. One person desired 2,000 copies of this bulletin and was willing to pay all the expense of issuing the special edition.

The economical use of skim milk from the dairy herd has been a subject of investigation, experiments have been carried on with several lots of pigs, and a bulletin has been issued giving the results of these experiments.

DAIRY BACTERIOLOGY.

The production of clean and wholesome milk is receiving more attention each year. If milk is ever to take the place it should among our food products, it will do so in part as a result of this campaign for the production of milk under better conditions. A study has been made of the conditions actually existing in various dairy barns of the state, and the milk produced under these various conditions has been tested for the amount of dirt and the number of bacteria. The city milk inspectors and the boards of health are demanding that the milk which is supplied to the cities shall be of a higher grade than it has been in the past. The Station has endeavored to assist the producers of milk in this state in securing a better quality of milk, and this work has apparently met with appreciation on the part of our dairy farmers.

There is another side to the problem of pure milk production that has not yet received the attention it demands. If the consumers must have purer and better milk, they must realize that it costs more to produce such milk and that the dairymen must receive for this better product an increased price. Were this realized in all cases, it would be a much easier task to persuade the dairymen that the production of purer milk is to their advantage.

FIELD EXPERIMENTS.

Field experiments have been conducted along horticultural lines. The growing of vegetables under canvas has been tried for two seasons and will be discontinued during the coming season. The spraying of potatoes will be reported upon by the Assistant Horticulturist. But little of the land of the College farm is suited to general plat experiments. Observations are made upon the results secured by various methods of treating

the field crops, and while this gives us valuable information, it does not give us the definite data which would be required for publication.

STATION FINANCES.

The funds available for Station work have not been increased during the past year. We receive one-half of the Hatch appropriation, namely, $7,500 annually, and $1,800 a year from the state. The printing of the Station bulletins and annual reports is paid for by the State Treasurer out of state funds.

With the small amount of money available for Station work it seems wise to pursue the policy which we have adopted in the past, namely, to confine our attention to a few lines of work and do this work most thoroughly.

In carrying out this policy we have had the hearty coöperation of the Board of Trustees of the Connecticut Agricultural College and of those officers of the College who have in any way been associated with the Station and its work.

L. A. CLINTON.

Report of the Dairy Husbandman.

To the Director of the Storrs Agricultural Experiment Station:

SIR:—I herewith submit a brief outline of the work in the dairy department during the past year.

FEED TRIALS WITH PIGS.

During the past year twelve lots of pigs have been fed skim milk and middlings. When fed in the proportion of one of middlings to four of milk, the cost of 100 pounds of gain was $4.45. When fed in the proportion of one of grain to eight of milk, the cost of 100 pounds of gain was $4.95.

CREAMERY PROBLEMS.

Samples of skim milk from hand separators and Cooley creamers have been collected and tested with the Babcock test. Pure cultures have been used in ripening cream, and the quality of butter has been compared with that made from cream ripened with skim milk starters. A large number of samples of cream have been tested, and a comparison has been made of the results of weighing and measuring samples.

FEEDING TRIALS WITH COWS.

An experiment was undertaken to show the value of nutrients in concentrates compared with the nutrients in roughages. Two dry cows of the same age and condition were fed a maintenance ration for a period of 100 days. Fifteen pounds of hay containing 7.4 pounds of dry matter were found to be equivalent to 6 pounds of corn meal containing 4.3 pounds of dry matter. The difference in the value of nutrients in grain and hay is attributed to a difference in the energy required for digestion. A similar trial with milch cows is also reported.

Blatchford's calf meal was fed to calves, and its feeding value was compared with that of skim milk. Exclusive of hay and grain eaten, 1 pound of gain in live weight was made from 1.09 pounds of nutrients in milk, while with the calf meal 1.79 pounds of nutrients were required for 1 pound of gain.

Respectfully submitted,

C. L. BEACH.

Report of the Poultryman.

To the Director of the Storrs Agricultural Experiment Station:

SIR:—The six months during which I have been connected with your Station has hardly been time enough to secure results in any research work, although considerable has been done.

While investigations into the squab industry are taking a large portion of my time, still a number of other experiments are receiving attention.

The hopper system of feeding, both with young chicks and laying hens, is being tested in all its branches; that is, by different feeds and with hens in confinement and on free range. The question of minimum cost of housing and feeding poultry is also being tested.

There have been a great many inquiries from all parts of the state regarding sick fowls, and eighty-three birds have been sent to the department for examination. In a great many of these cases satisfactory information was furnished to the persons concerned, but in a few cases it was thought advisable to visit the "plants." In every case but one where the plant was visited the trouble could be traced to improper care. The one exception was a case of poisoning.

Respectfully submitted,

C. K. GRAHAM.

Report of the Chemist.

To the Director of the Storrs Agricultural Experiment Station:

SIR:—During the summer of 1904 I utilized a considerable part of my vacation in studying the chemistry of proteolytic changes and products in Strassburg under Professor Franz Hofmeister, with special reference to the work being carried on here in making soft cheeses. This experience has been of inestimable advantage to me in advising upon this work.

In June, 1905, Mr. A. W. Bosworth, B. S., resigned his position as chemical cheese expert. Mr. A. W. Dox, B. S. (Univ. of Pa.), A. M. (Columbia), has been appointed in his place. Mr. H. D. Edmond has rendered valuable help in the work of this department since his appointment as assistant in the College in November, 1904, and is now recognized as an assistant chemist to the Experiment Station.

Apart from the special cheese investigation to which Mr. Bosworth devoted his time, most of the chemical work has been done in connection with experiments in other departments and is therefore considered elsewhere. Analyses have been made by the Station chemist and assistant of milks, feeds, fertilizers, manures (for digestion experiments), cheeses (determination of different classes of nitrogen compounds), suspected foods and stomach contents (qualitative tests for poisons), air (determination of carbon dioxide), rocks, etc. Preliminary work, which is not yet in a stage to report, has been done along three lines: (1) the nature of the flavoring substances in Roquefort cheese; (2) the connection between soil fertility and analyses by special methods of extraction; and (3) the growth of the potato plant and the quality of its tubers. Pot experiments in connection with the last two were carried on this season (1905). This work will necessarily extend over a considerable time.

The equipment of the department has been liberal enough to free the work from any great trouble on that score. We are sadly cramped for room, however, three men having to work in a space barely sufficient for one. An addition to our laboratory space of at least one other good-sized room is urgently required if the growing needs of the work are to be met.

Respectfully submitted,

B. B. TURNER.

Report of the Bacteriologist.

To the Director of the Storrs Agricultural Experiment Station:

SIR:—A number of lines of bacteriological work have been conducted by this department during the year ended June 30, 1905. Some of these are continuations of investigations which were begun before the beginning of the year. Certain of these investigations have progressed sufficiently to be reported upon, and the results obtained will be found elsewhere in this report. Some of the more technical lines of work which have been running for some years are still incomplete, and no report will be given at present. During the year a number of special problems have been investigated. Some of these will be reported in this volume, while certain others are still in process of investigation, and not sufficiently completed to warrant a report at this time.

The bacteriological and sanitary studies of market milk mentioned in my last report have occupied a considerable amount of time during the year, and sufficient results to warrant publication have been obtained from two series of investigations. The purpose of this work is to obtain more definite knowledge in regard to the sanitary condition of milk produced by the dairymen of the state; and in this work not only the milk but the stable conditions of the dairies have been studied, with the results given in the article entitled "Studies of Market Milk" found in this report. In view of the present agitation on the part of city officials and the general public toward a cleaner milk supply, it is of great importance to know definitely the quality of the milk when it leaves the hands of the producer. While the results given in the present article indicate the quality of the milk produced by dairymen in two localities, the writer believes that they are not representative of many sections of our state, and intends to continue this line of investigation in other sections.

During the year a considerable number of samples of milk and cream have been sent to this department by dairymen and dealers in various parts of the state. These have been tested, and reports given to those sending the samples. Several dairymen in the eastern part of the state who are sending milk to Boston have had their milk condemned by the Boston milk officials because of its too great germ content. A number of these men have applied to the Station for help, and the writer has visited some farms, giving suggestions in regard to methods of cleanliness in the stables, which have resulted in the milk's being again accepted by the Boston authorities.

In coöperation with the dairy division a series of bacteriological studies was made in connection with the use of different butter starters. The results of this work are reported by Professor Beach.

The bacteriological work in connection with the soft cheese problems has been continued from the previous year, and considerable work in these lines has been done during the year.

An extended series of experiments is being made to determine the effect of stable conditions and of various methods of milking upon the germ content, keeping quality, and sanitary condition of milk. This work is not yet completed, but a report upon the results thus far obtained is given in this report. The work, however, will be continued.

Respectfully submitted,

W. A. STOCKING, JR.

Report of Supervising Bacteriologist.

To the Director of the Storrs Agricultural Experiment Station:

The bacteriological work of the Station the last year has comprised several series of experiments. A part of these have been carried out under the direction of Mr. W. A. Stocking and are reported by him in another part of this report. The work done under my own personal direction has been conducted partly at Storrs and partly at Middletown. This work has comprised two lines of investigation.

1. The work undertaken by the Station upon Camembert cheese has involved a considerable amount of bacteriological study. While it has become abundantly proved that the chief agent in the ripening of these cheeses is a mold, it has been also clear that bacteria play an important and necessary part in this ripening. Exactly what their agency is it has been difficult to determine, and it has hitherto not been understood. A large number of cheeses of our own make, of cheeses bought in the market, and of cheeses imported especially from Europe for our work have been subjected to bacteriological analysis. A part of the results have already been published in Bulletin No. 35, and a fuller report will appear later. The essential result of this work is to show that the only bacteria necessary to the ripening of the cheese are the common lactic bacteria. Ideally ripened Camemberts have been found containing, at least within the rind, no other varieties of bacteria. When other species are present various kinds of abnormal ripening are usually the result.

2. The second line of investigation, far more extensive than the first, has been upon the systematic study and classification of dairy bacteria. This work was begun several years ago and has involved a large amount of labor. Hundreds of varieties of bacteria from different sections of the country, as well as from Europe, have been studied. The work has progressed so

far as to render it desirable to publish the results. But the American Society of Bacteriologists are planning to adopt during the present year a uniform scheme for bacteriological description. It would be useless to publish our descriptions until after this uniform plan has been decided upon. It has been thought best, therefore, to continue the work during the present year, both for the purpose of obtaining more data before publication, and in order that the descriptions, when published, may conform to the plan adopted by the Bacteriological Society. It is expected that this work will be published in the next annual report.

Respectfully submitted,

H. W. CONN

Report of the Mycologist.

To the Director of the Storrs Agricultural Experiment Station:

SIR:—The mycologist of the soft cheese investigation has continued the work outlined in the first report. The special studies upon the mycology of Camembert have been already briefly reviewed in Bulletin 35 of this Station. A detailed paper covering the technical part of the work done is now nearly completed. This will present the results of the work already done upon Roquefort cheese as well as upon Camembert. There will also be a brief review of mycological examinations of the other types of soft cheese found upon the American market. These and related lines of experiment and study are being continued. The study of the dairy molds in general has led to the proposal of methods of description for this type of organisms based upon their relation to standard culture media. This series of studies was reviewed before the meeting of the American Mycological Society at the December meeting, 1904. The study and collection of the species of the genus *penicillium* has brought out many interesting forms, but the work is still too far from completion to present it for publication at this time.

Respectfully submitted,

CHARLES THOM.

Report of the Assistant Horticulturist.

To the Director of the Storrs Agricultural Experiment Station:

SIR:—The work in this department is being carried on along practically the same lines as last year.

1. Four plots of potatoes are being grown for the purpose of determining the minimum number of applications of Bordeaux that will prevent potato rot.

2. Plots of cucumbers and melons have been planted for the study of melon blight.

3. The cultural and spraying experiment with tomatoes made last year is being repeated this season.

4. The ground shaded with cloth has been planted to vegetables with duplicates outside, the same as last year.

5. During the winter asparagus and rhubarb growing in the cellar was tried.

6. An experiment to determine the relative value of pistillate and staminate asparagus plants has been made.

The results of these six experiments are given in this report.

An apple orchard of 125 trees has been planted on rough waste land to determine whether land that is too rough to plow can be utilized to advantage in orcharding.

A number of market gardens and orchards have been visited in studying plant diseases and the market garden industry of the state.

Respectfully submitted,

E. R. BENNETT.

TESTING COWS FOR ADVANCED REGISTRY.

BY C. L. BEACH.

The admission of dairy cattle to advanced registration is based upon production. For a mature cow (five years old or more) the requirement for the year's record is a yield of not less than 500 pounds of butter, 400 pounds of fat, or 10,000 pounds of milk for the Jersey; 360 pounds of fat for the Guernsey; 8,500 pounds of milk and 375 estimated butter for the Ayrshire; and 10,700 pounds of milk and 375 of butter for the Holstein. The requirements for admission in the two-year form are from 60 to 70 per cent. of those in the full age form, and for animals between two and five years old they are in proportion to age.

TABLE I.

Robin Butterfly, 3rd, A. J. C. C. No. 187,089. Age, 2 years and 8 days. Owned by Connecticut Agricultural College.

MONTH.	Lbs. Milk.	Per Cent. Fat.	Lbs. Fat.	Estimated Lbs. of Butter.
October 13-31,	302.8	5.8	17.56	20.48
November,	399.2	6.6	26.34	30.73
December,	405.6	6.8	27.58	32.17
January,	373.7	6.5	24.29	28.34
February,	330.6	6.4	21.15	24.68
March,	358.7	7.6	27.26	31.80
April,	316.2	6.4	20.23	23.60
May,	382.7	5.4	20.66	24.10
June,	441.7	6.5	28.71	33.50
July,	389.2	6.3	24.51	28.60
August,	353.6	6.4	22.63	26.40
September,	387.1	7.3	28.25	32.96
October 1-12,	49.9	7.3	3.64	4.25
	4491.0	—	292.81	341.61

The records of six cows here given exceed the requirements of the advanced registry of the respective cattle clubs, and conform to the rules by which such tests are made except as to the method of certification. These six animals are owned, and four of them were bred, by the Connecticut Agricultural College:

ROBIN BUTTERFLY, 3D.

Robin Butterfly, 3rd, was 2 years 8 days old at the beginning of the test. Feed consumed during the year, 1,139 pounds of hay, 7,025 pounds of silage, 1,665 pounds of grain, with 126 days at pasture. Record for the year, 293 pounds of fat. Requirements for admission to Registry of Merit, 260 pounds of fat (see Table 1, page 24).

ROBIN BUTTERFLY, 2D.

Robin Butterfly, 2nd, was 2 years and 149 days old at the beginning of the test. Feed consumed during the year, 511 pounds of corn stover, 575 pounds of hay, 7,944 pounds of corn silage, 1,116 pounds of grain, 126 days at pasture. Record for the year, 292 pounds of fat. Requirements for admission to Registry of Merit (when less than 30 months old) 260 pounds of butter fat.

TABLE 2.

Robin Butterfly, 2d, A. J. C. C. No. 162,567, Age 2 years and 149 days. Owned by Connecticut Agricultural College.

MONTH.	Lbs. of Milk.	Per Cent. of Fat.	Lbs. of Fat.	Estimated Lbs. of Butter.
May 28 to 31,	11.5	7.2	.82	.95
June,	283.2	5.0	14.16	16.52
July,	560.9	5.1	28.60	33.36
August,	504.9	5.45	27.51	32.10
September,	532.2	5.65	30.06	35.07
October,	407.3	6.6	26.68	31.13
November,	351.3	6.4	22.48	26.23
December,	360.2	6.9	24.85	28.99
January,	406.5	6.6	26.82	31.29
February,	302.0	6.77	20.44	23.85
March,	354.8	6.3	22.35	26.07
April,	340.1	6.3	21.42	24.99
May 1 to 27,	347.3	7.5	26.04	30.38
	4762.2	—	292.23	340.93

Robin Butterfly, 2nd, is full sister to Robin Butterfly, 3rd, with record of 293 pounds of butter fat at two years of age; daughter of Robin Butterfly, with record of 463 pounds of fat; and granddaughter of Butterfly Maid, with record of 15.37 pounds of butter in seven days.

STILETTO.

Age of cow at beginning of test, 3 years and 39 days. Requirements for admission to Advanced Registry, 6,607 pounds of milk and 280 pounds of butter. Record for the year, 6,707 pounds of milk and 307 pounds of butter. Feed consumed during year, 1,929 pounds of hay, 9,100 pounds of silage, 1,902 pounds of grain, 119 days at pasture.

TABLE 3.

Stilleto, Ayrshire Herd Record No. 16,706, Age of Cow, 3 years and 39 days. Owned by Connecticut Agricultural College.

MONTH.	Lbs. of Milk.	Per Cent. of Fat.	Lbs. of Fat.	Estimated Lbs of Butter.
October 23-31,	252.1	3.8	9.58	11.17
November,	761.6	3.9	29.70	34.65
December,	727.3	4.2	30.54	35.64
January,	682.2	4.1	27.97	32.63
February,	587.8	3.9	22.93	26.75
March,	572.8	4.0	22.91	26.73
April,	481.4	3.9	18.77	21.91
May,	497.3	3.6	18.30	21.35
June,	549.5	3.6	19.78	23.07
July,	462.3	3.2	14.79	17.25
August,	479.8	4.8	23.03	26.87
September,	453.5	3.9	17.68	20.63
October 1-22,	199.5	3.6	7.18	8.37
	6707.1	—	263.16	307.02

POLLY OF MAUCHLINE.

Polly of Mauchline is an imported Ayrshire cow. She consumed during the year, in addition to pasture, 1,460 pounds of hay, 10,665 pounds silage, and 2,872 pounds of grain. Record for the year, 9,322 pounds of milk and 425 pounds of butter. Requirements for admission to advanced Registry, 8,500 pounds of milk and 375 pounds of butter.

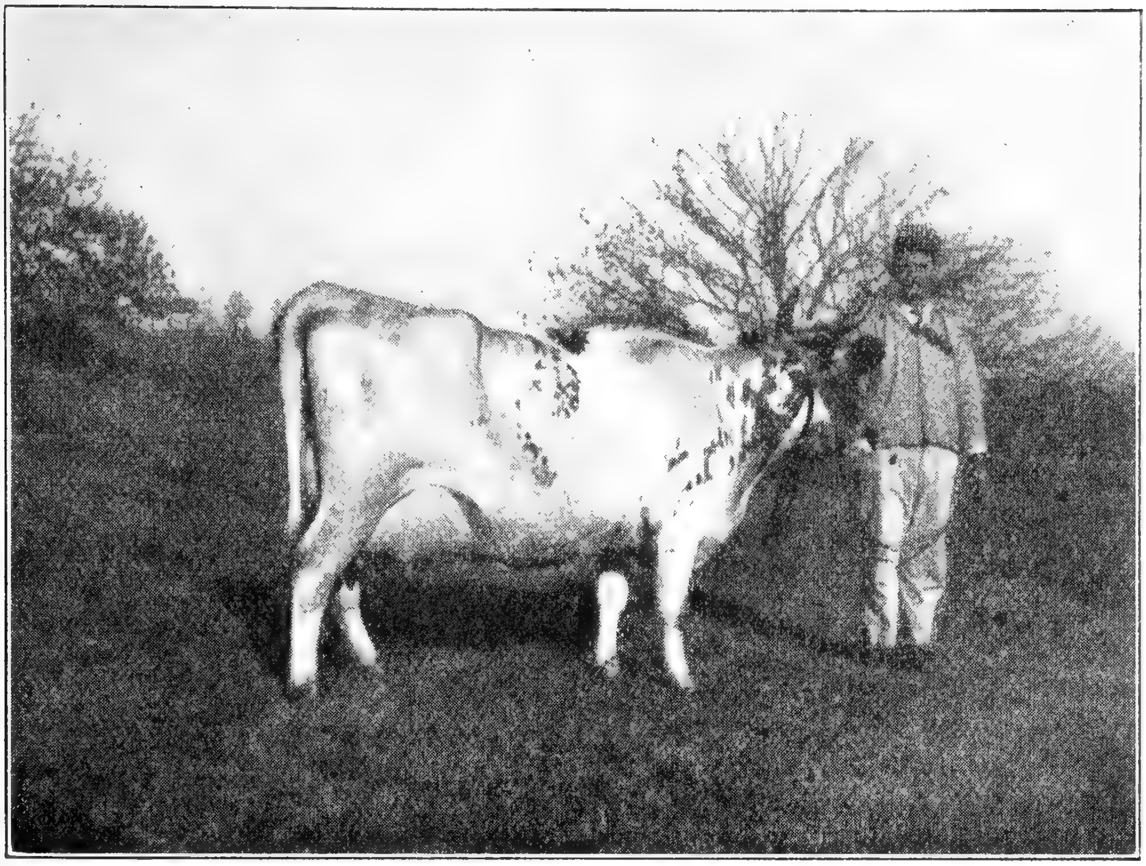

FIG. 1.—Polly of Mauchline, A. H. R. No. 12,294.
Record for one year: 9,322 pounds of milk; 425 pounds of butter.

TABLE 4.

Polly of Mauchline, Ayrshire Herd Book No. 12,294. Age, 6 years. Owned by Connecticut Agricultural College.

MONTH.	Lbs. of Milk.	Per Cent. of Fat.	Lbs. of Fat.	Estimated Lbs. of Butter.
November 5-30,	994.2	3.8	37.77	44.06
December,	1084.7	3.6	39.04	45.54
January,	1190.2	4.1	48.79	56.92
February,	1084.6	4.2	45.55	53.14
March,	788.3	4.1	32.32	37.70
April,	724.8	4.0	28.99	33.82
May,	710.9	3.6	25.59	29.85
June,	793.4	3.5	27.76	32.38
July,	612.3	3.8	23.26	27.13
August,	506.1	3.8	19.23	22.43
September,	385.0	4.5	17.32	20.20
October,	393.9	4.3	16.93	19.75
November 1-4,	53.9	4.3	2.31	2.69
	9322.3	—	364.86	425.61

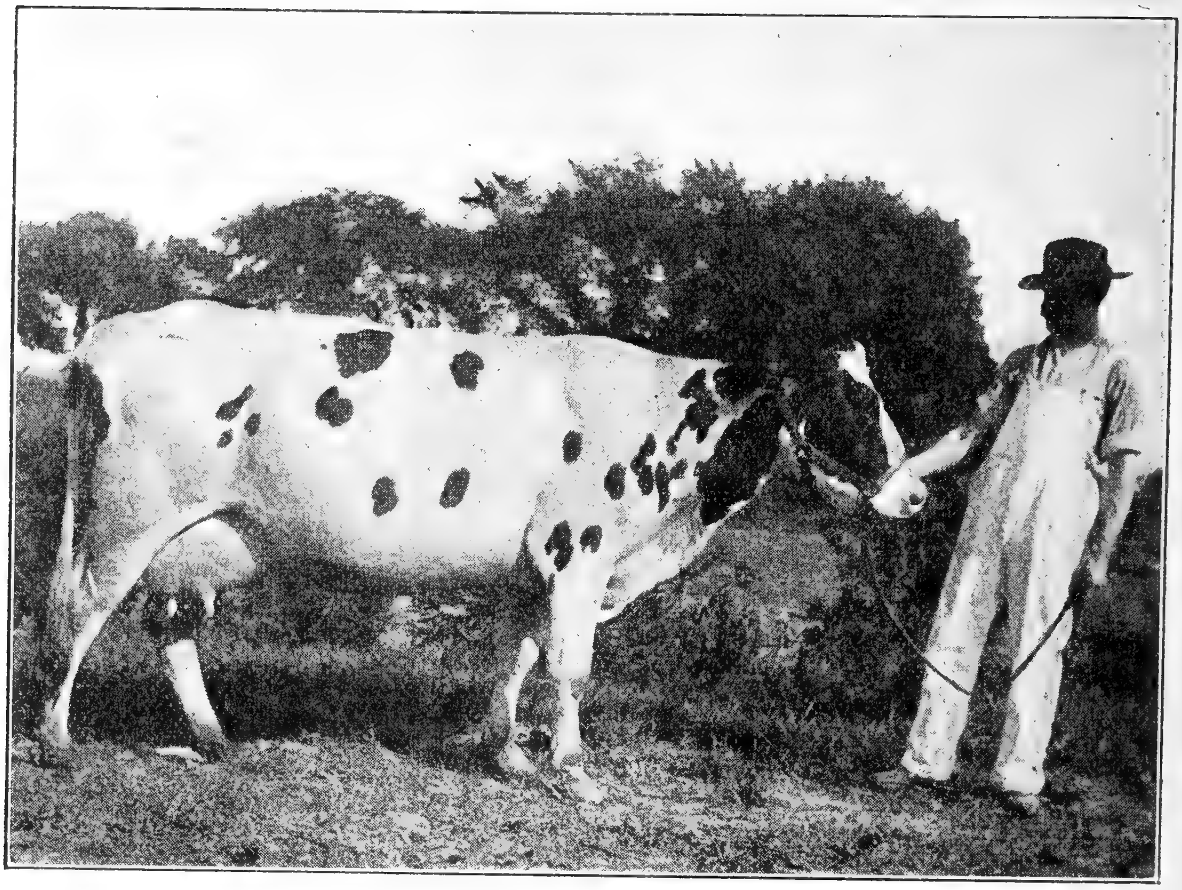

FIG. 2.—Altoana Pietertje A., H. F. R. No. 54,656.
Record for one year: 13,050 pounds of milk; 527 pounds of butter.

TABLE 5.

Altoana Pietertje A, Holstein Friesian Registry No. 54,656. Age 6 years. Owned by the Connecticut Agricultural College.

MONTH.	Lbs. of milk.	Per Cent. of Fat.	Lbs. of Fat.	Estimated Lbs. of Butter.
December 15–31,	639.0	3.4	21.72	25.34
January,	1533.9	3.6	55.22	64.42
February,	1363.2	4.6	62.70	73.16
March,	1447.4	3.4	49.21	57.41
April,	1374.4	3.2	43.98	51.31
May,	1486.5	3.2	47.56	55.48
June,	1240.5	3.0	37.21	43.41
July,	929.0	2.8	26.01	30.34
August,	890.0	3.2	28.48	33.22
September,	844.2	2.1	26.10	30.45
October,	624.1	3.6	22.48	26.24
November,	489.0	4.6	22.49	26.24
December 1–14,	191.2	4.6	8.79	10.25
	13050.4	—	451.95	527.27

ALTOANA PIETERTJE A.

Altoana Pietertje A is a Holstein cow, 6 years old. She consumed during the year 1,487 pounds of hay, 11,820 pounds silage, 3,752 pounds of grain, and was at pasture 105 days. Record for year, 13,050 pounds of milk and 452 pounds of fat. Required for admission to Advanced Registry, 10,700 pounds of milk.

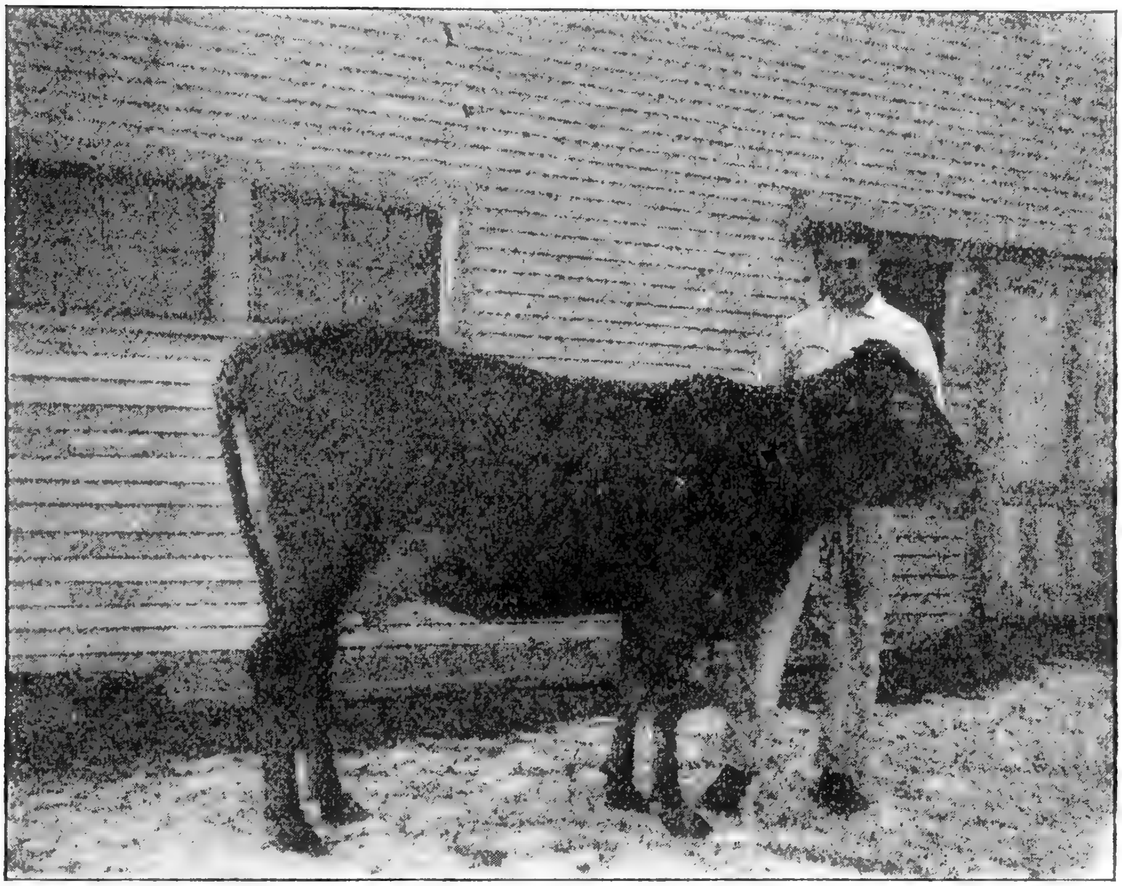

FIG. 3.—Eurotas, 2d, A. G. C. C. No. 14,067.
Age, 3 years and 234 days. Owned by Connecticut Agricultural College.

EUROTAS, 2D.

Eurotas, 2nd, is a Guernsey heifer, 3 years and 234 days old at the beginning of the test. She consumed during the year 1,087 pounds of hay, 7,895 pounds of silage, 2,500 pounds of grain, and was at pasture 105 days. Yield of butter fat for year, 332.5 pounds. Requirements for admission to Advanced Registry, 310.4 pounds of butter fat.

TABLE 6.

Eurotas, 2nd, A. G. C. C. No. 14,067, Age, 3 years and 234 days. Owned by Connecticut Agricultural College.

MONTH.	Lbs. of Milk.	Per Cent. of Fat.	Lbs. of Fat.	Estimated Lbs. of Butter.
January 12-31,	487.3	5.3	25.82	30.12
February,	696.8	4.2	29.26	34.14
March,	739.9	4.7	34.77	40.56
April,	665.1	4.2	27.93	32.59
May,	706.5	4.7	33.20	38.73
June,	681.8	4.4	29.99	34.99
July,	642.2	4.6	29.54	34.46
August,	631.3	4.6	29.03	33.87
September,	649.7	4.9	31.83	37.13
October,	560.1	5.0	28.00	32.67
November,	412.3	4.5	18.55	21.64
December,	237.7	5.2	12.36	14.42
January 1-11,	42.5	5.2	2.21	2.58
	7153.2	—	332.49	387.88

In coöperation with the Ayrshire association, four cows owned by H. Dorrance of Plainfield, Conn., were tested for the Advanced Registry.

The milk from each cow for each milking was weighed and recorded by the owner. Once each month samples of milk were sent to the Station for the Babcock test. Three times during the year a representative of the Station visited the farm, weighed the milk, and collected samples for a check test. The records of the four cows are given in the table:

TABLE 7.

Herd of H. Dorrance, Plainfield, Conn.

NAME OF COW.	Herd Book No.	AGE OF COW AT BEGINNING OF TEST.			REQUIREMENTS FOR AGE.		RECORD OF COW.		
		Yrs.	Mos.	Days.	Lbs. of Milk.	Lbs. of Fat.	Lbs. of Milk.	Per cent. of Fat.	Lbs. Butter.
Molly Fryer,	16,051	6	8	8	8500	375	9741	4.02	453
Ruby Russel,	15,564	6	2	23	8500	375	8643	3.78	382
Dorris Y,	16,351	3	7	5	7086	305	7807	4.10	365
Dolly Fryer, 2nd,	17,094	2	7	17	6118	256	6485	4.03	299

RECORD OF FIVE DAIRY HERDS.

In coöperation with the owners, the Station has secured the milk and fat records for one year of the individual cows in five herds. The Station furnished the milk sheets, loaned the milk scales, and collected and tested the samples. The owners of the herds weighed and recorded the amount yielded by each cow, and once each month took a composite sample of six milkings.

TABLE 8.

Milk and Butter Fat Yields of Five Herds.

	No. 1.		No. 2.		No. 3.		No. 4.		No. 5.	
	Lbs. of Milk.	Lbs. of Fat.	Lbs. of Milk.	Lbs. of Fat.	Lbs. of Milk.	Lbs. of Fat.	Lbs. of Milk.	Lbs. of Fat.	Lbs. of Milk.	Lbs. of Fat.
1, - -	5496	272	5686	289	5627	344	6418	307	7157	421
2, - -	3605	225	4731	260	5745	311	5330	287	6939	418
3, - -	4665	212	5731	235	5387	297	6046	286	4589	290
4, - -	4271	199	3802	230	5644	292	5291	277	4548	264
5, - -	3410	198	4146	229	6209	285	5124	255	4452	264
6, - -	2453	190	4233	225	5866	284	4245	253	4030	259
7, - -	2979	189	3619	223	5347	274	—	—	—	—
8, - -	3333	179	4721	222	4832	267	—	—	—	—
9, - -	3193	165	4394	215	8165	262	—	—	—	—
10, - -	2999	163	4078	205	3942	251	—	—	—	—
11, - -	2582	151	3057	192	4348	247	—	—	—	—
12, - -	2701	135	3131	150	4485	230	—	—	—	—
13, - -	—	—	—	—	5285	228	—	—	—	—
14, - -	—	—	—	—	4027	225	—	—	—	—
15, - -	—	—	—	—	4050	211	—	—	—	—
16, - -	—	—	—	—	4444	207	—	—	—	—
17, - -	—	—	—	—	4084	204	—	—	—	—
18, - -	—	—	—	—	3799	198	—	—	—	—
19, - -	—	—	—	—	3557	193	—	—	—	—
20, - -	—	—	—	—	3989	180	—	—	—	—
21, - -	—	—	—	—	3400	177	—	—	—	—
22, - -	—	—	—	—	2536	129	—	—	—	—
	3474	190	4277	223	4762	241	5409	278	5286	319

The individual production of butter fat ranged in herd No. 1 from 135 pounds to 272 pounds; in herd No. 2 from 150 pounds to 289 pounds; in herd No. 3 from 129 pounds to 344 pounds; in herd No. 4 from 253 pounds to 307 pounds; and in herd No. 5 from 259 pounds to 421 pounds.

The average production of butter fat ranged from 190 pounds in herd No. 1 to 319 pounds in herd No. 5. The difference in the average production of these two herds might be attributed in part to a difference in feeding, care, and management. In the opinion of the writer, however, the variance in a large measure was due to the difference in the breeding and the individuality of the cows in the two herds.

Dividing the herds into three divisions according to productive capacity, we have the following table:

TABLE 9.

Butter Fat Yield of Five Herds.

No. of Herd.	Best Cows.		Medium Cows.		Poorest Cows.	
	No. of Cows.	Average Fat Production.	No. of Cows.	Average Fat Production.	No. of Cows.	Average Fat Production.
1,	4	227	4	189	4	154
2,	4	254	4	225	4	190
3,	7	298	7	244	8	214
4,	2	297	2	281	2	254
5,	2	419	2	277	2	261
	—	299	—	243	—	215

POULTRY SUGGESTIONS FOR THE AMATEUR.

BY C. K. GRAHAM.

INTRODUCTION.

Many people raise a few chicks for their own use, while others grow a few broilers for the local market, but not enough to justify them in investing the money necessary to equip a model poultry plant. A few months ago a bulletin was issued by this Station setting forth the particulars of a model brooder house.

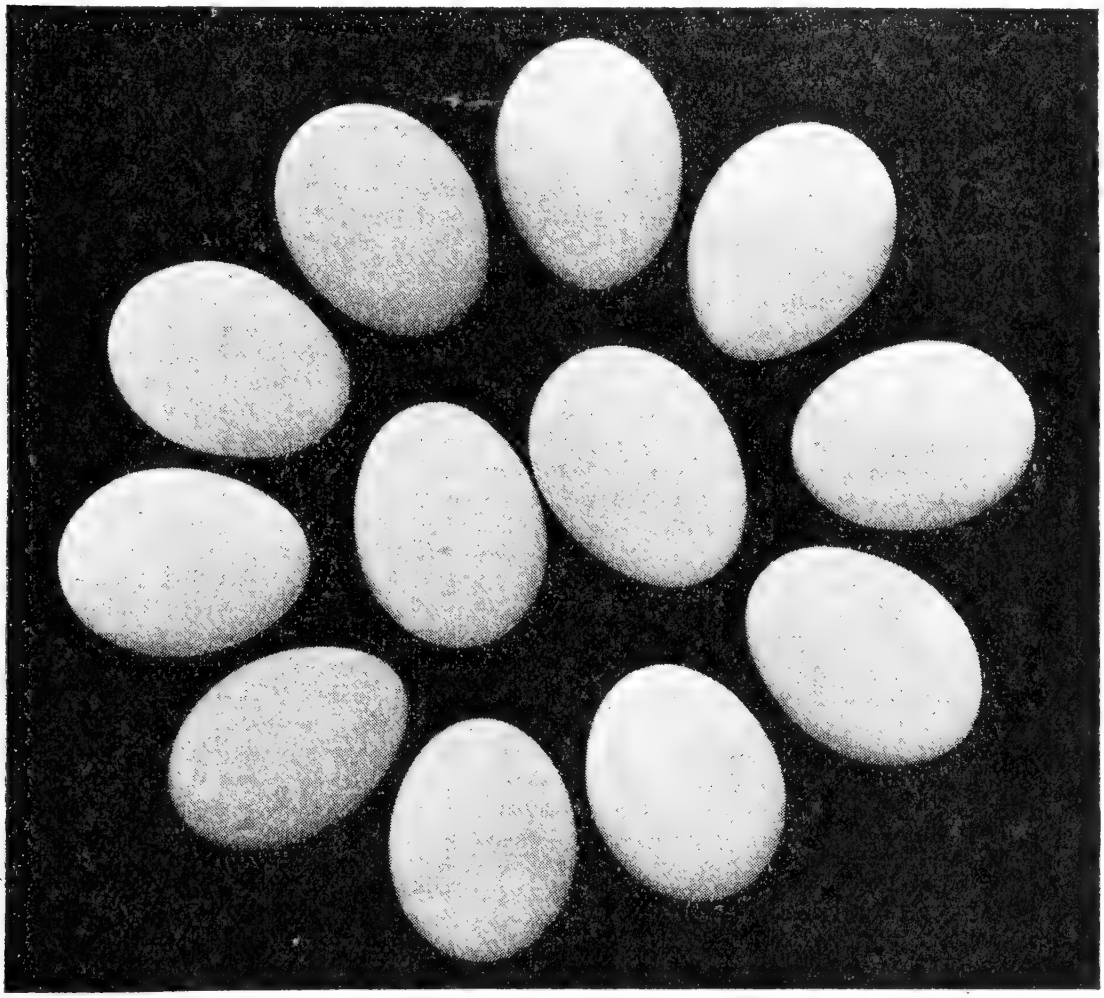

FIG. 4.—A fair sitting of eggs.

Its publication has brought in many inquiries for a brooder that will cost less and yet give satisfactory results to the small producer. This bulletin is published to answer some of the

questions received. It is not intended to give the results of experiments, but to assist the amateur who desires to keep a few chicks for pleasure as well as for profit.

Selecting Eggs for Hatching.—Money should in every case accompany orders for eggs. The shipper may be expected to give fair sized, smooth eggs from healthy birds. During the breeding season frequent complaints of unfair treatment in this respect are received. Investigation shows that the most of these spring from ignorance of what a good sitting of eggs is.

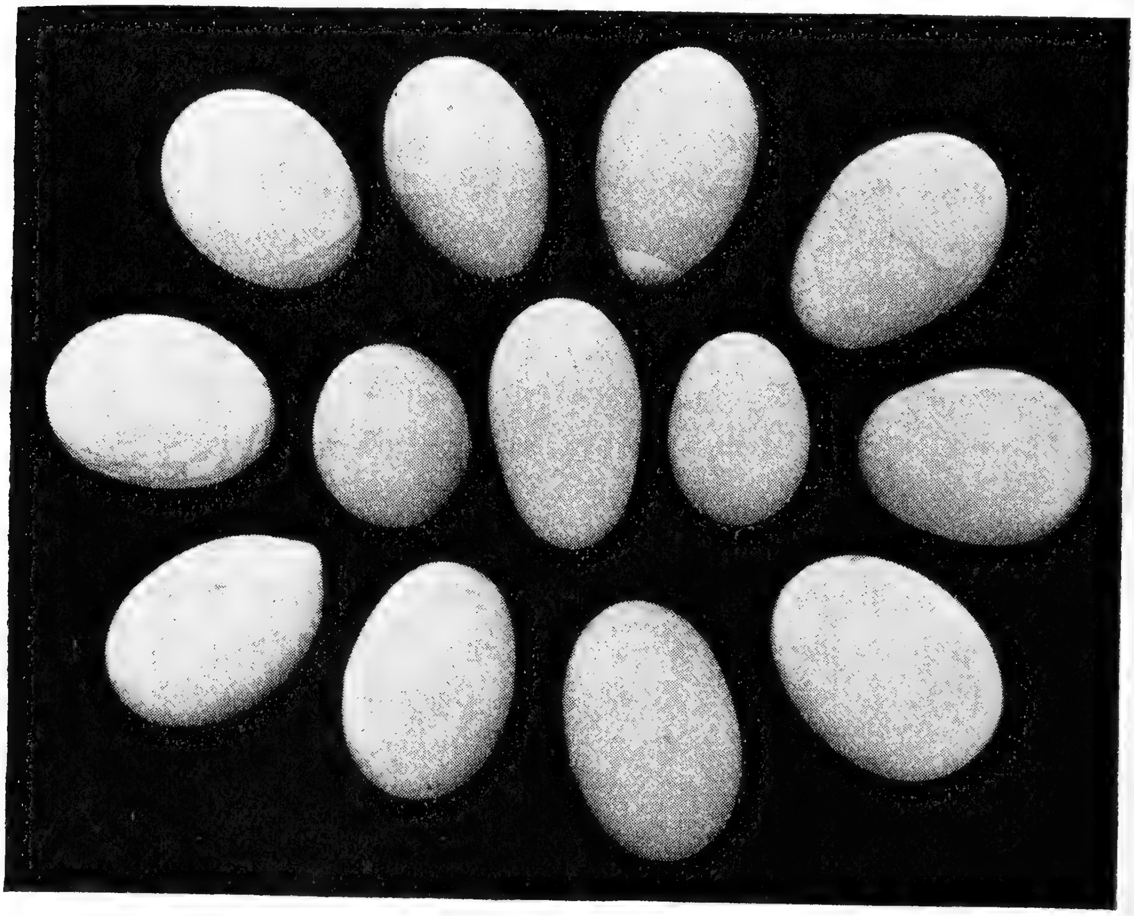

FIG. 5.—Some eggs that should be avoided when selecting for hatching.

Fig. 4 shows a fair sitting; while Fig. 5 shows a few eggs which should be avoided. Rough shelled, dirty, and mottled eggs with thin shells should also be excluded.

Small Eggs.—There is some doubt as to the advisability of setting small eggs. While it is possible that they may be as fertile and produce as many chicks as larger eggs, it is probable that pullets from the former will have a tendency to lay small eggs. For this reason, if for no other, shippers should avoid sending out small eggs, since they are likely to injure the reputation of the breed in the locality where they are sent.

Age of Eggs.—It is not advisable to buy eggs which are over five days old when shipped. Every egg should be carefully dated when taken from the nest in order to avoid error on this point. While good hatches have been secured from eggs that were three weeks old when placed in the incubator, as a rule they cannot be expected to hatch well after they are ten days old.

Packing Eggs for Hatching.—Too much care cannot be taken in packing. Fig. 6 shows a properly prepared package. There are two classes of general express, viz.: box, and handle packages. The former are likely to be thrown; while the latter are always carried. An ordinary basket with plenty of excelsior

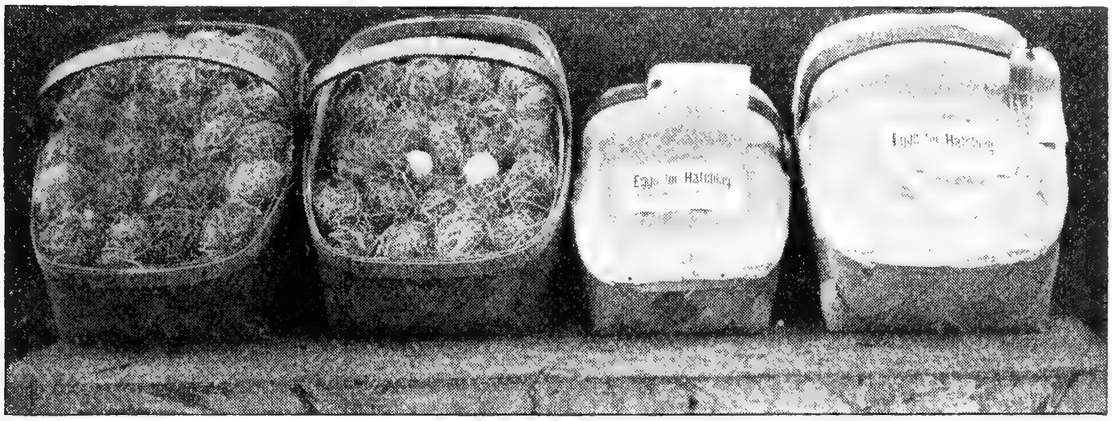

FIG. 6.—Eggs ready for shipment. The baskets on the left show the method of wrapping each egg.

in the bottom, and sides well cushioned, makes an excellent receptacle. Into this the eggs, carefully wrapped, should be packed, and over them plenty of padding placed. Cheese cloth or cotton tacked over the top forms a satisfactory covering. Such a package, conspicuously labeled "*Eggs for Hatching*," can be shipped any distance and will reach its destination in good condition. Upon receipt of the package the eggs should not be removed until the hen or incubator is ready to receive them; but the basket should be turned over daily.

Sitting Hens.—Almost any broody hen can be made to sit if carefully handled. She should not be carried by the legs with her head hanging down, but with her breast resting in the palm of the hand. Transfer should be made at night, and the nest into which she is put kept dark for twenty-four or thirty-six hours.

Dusting Sitting Hens.—A sitting hen should be carefully but thoroughly dusted when first put upon the nest and twice thereafter, the last time being about the nineteenth or twentieth day.

Nests for Sitting Hens.—Fig. 7 shows a very simple house or series of nests for sitting hens. The nest may be kept dark

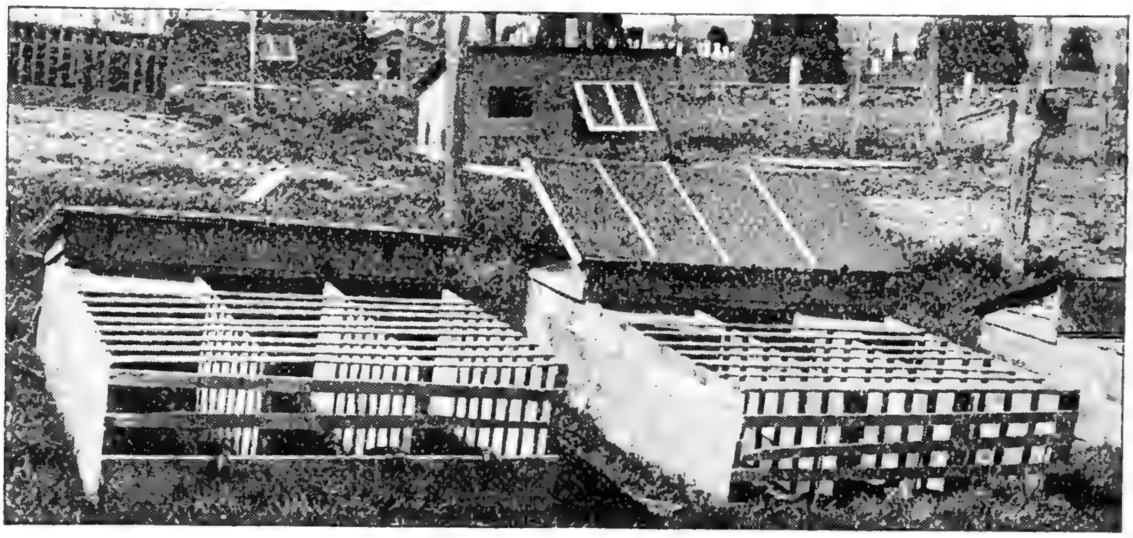

FIG. 7.—Front view of nests and runs used for sitting hens.

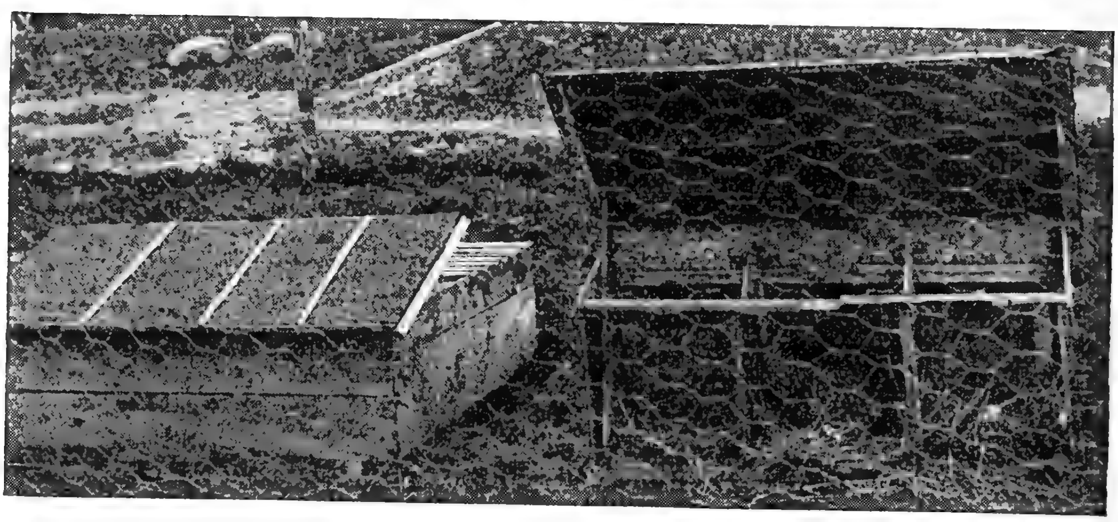

FIG. 8.—Rear view of nests with back removed to show the hen sitting.

by closing the door in front. The walk is about four feet long and as wide as the nest. A series of three nests makes a width of four feet, so that ordinary lath may be used for the top and ends of the walk. Fig. 8 shows the same nest box with the back taken off and the interior disclosed.

Rearing Incubator Chicks by Broody Hens.—A hen to which incubator chicks are to be given should be free from lice and in a nest where other hens cannot disturb her. In the evening two or three chicks, at least thirty-six hours old, may be placed under her from behind, care being taken not to excite her, lest she step on them. At least one chick of each color should be

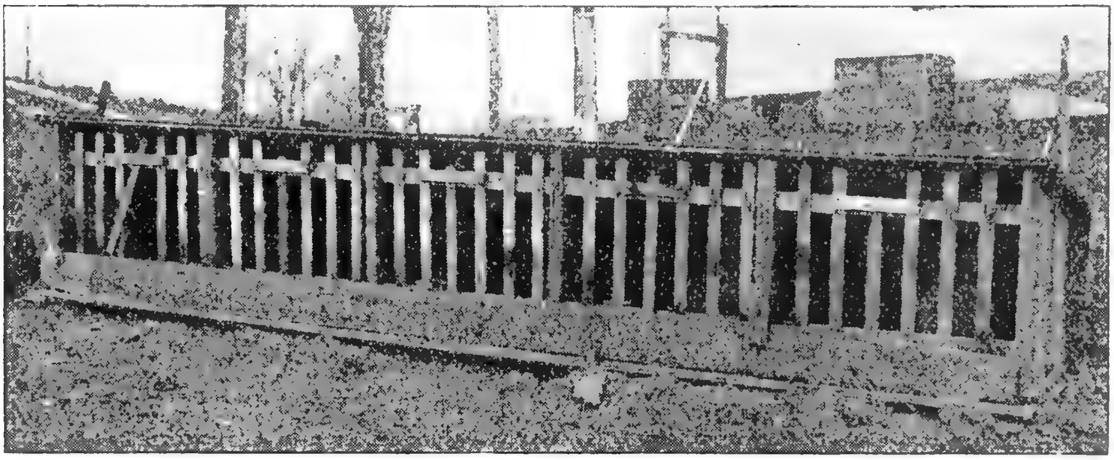

FIG. 9.—Row of coops used for hens with chicks for first week.

FIG. 10.—Coop for hen and chicks after first week.

given her, for hens are apt to kill chickens of another breed, color, or size than those they have already adopted. The following morning she may be expected to mother as many as are given her.

The first week is the most critical period in the life of the chick. Trouble is most likely to be caused by chills. Fig. 9 shows a row of coops that have proved very satisfactory.

They are about two feet square, and have a six-inch board along the front so that the chicks cannot get away from the mother. As soon as they are lively enough to fly over this board they are moved to a coop such as is shown in Fig. 10, where they may have free range. The slat coop in front affords the hen opportunity for exercise. This coop is about thirty inches square and two feet high in the center. The floor draws out and can be easily cleaned, while the door in front excludes intruders at night. Ventilation is secured by a few small holes in the ends. The slat yard is made of four foot lath. One end is closed, the other fitted to the end of the small coop. It is not advisable to allow the hen free range for at least two weeks. If she is kept confined and fed coarse grains, while the chicks are being fed a few yards away on finer grains, she will soon forget to call them and probably will start to lay in three or four weeks, and at the same time will continue to protect the chicks during nights and unpleasant weather. If the chicks are to be distributed among several hens, it will be advisable to make colonies, care being taken to put those of about the same age together. Chicks of different ages should not be fed together, since the smaller ones will be crowded from the grain and will not thrive.

Rearing Chicks with Brooders.—Many people prefer the artificial method of raising chicks, but want "something cheap." It is not always wise, however, to use the "cheapest." Fig. 11 shows a brooder made out of an old packing case. A similar one which will accommodate fifty chicks can be built for about a dollar. This brooder has given excellent results, but must be used in a shed or colony house. The brooder proper is made of four ten-inch boards, three feet long, on which is nailed a tin or galvanized iron cover. Above this, around the sides, are strips one inch thick, and on these strips sits the floor of the brooder. There should be a couple of one-inch holes in each strip to admit air. The floor should be made of matched lumber. In the center an eight-inch hole should be cut, and over this an old tin pan, about ten inches across at the top (which is now to become the bottom) and four inches deep, should be placed. The sides of this tin should be punched full of holes. For a hover a table two feet six inches square, with

legs about four and one-half inches long, may be used. Cheap felt may be tacked on for a curtain, care being taken that it is cut from top to bottom every five or six inches. For an outside wall four four-inch strips, three feet long, nailed together,

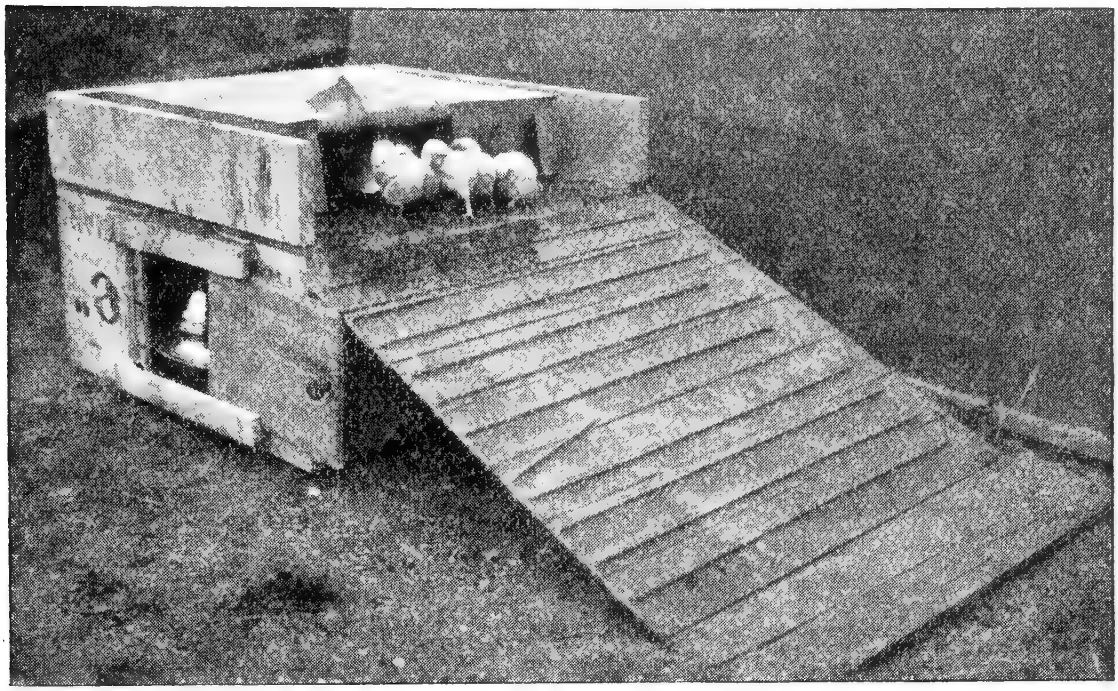

FIG. 11.—Home made brooder.

and set on the brooder, will be satisfactory. When the chicks are ten days old, one side may be taken away, and a bridge used so that they may run from under the hover direct to the floor of the room. Fig. 14 shows the lamp used in this brooder. The

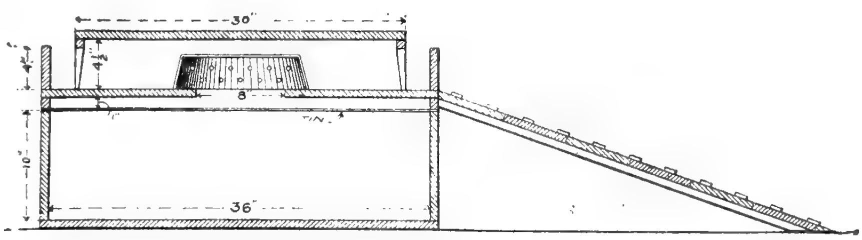

FIG. 12.—Cross section of home made brooder house.

burner can be bought for twenty-five cents, and the bowl may be made of a two-quart tin basin covered with a small pie plate turned bottom side up. This plate should have a hole punched in it and should be fastened to the collar of the burner with a drop of solder. It is also advisable to fasten the plate to the basin in the same way.

Winter Chicks.—Fig. 13 shows a brooder in which thirty chicks have been housed since Feb. 1st of this year, and in spite of more or less zero temperature there has been little difficulty in keeping the thermometer above ninety degrees. The records show that although it stood in an open field all the time, it consumed only about a pint of oil a day during the first two months. This style of brooder can be bought of almost any incubator firm for from twelve to sixteen dollars. It is supposed to accommodate fifty chicks, but during the season

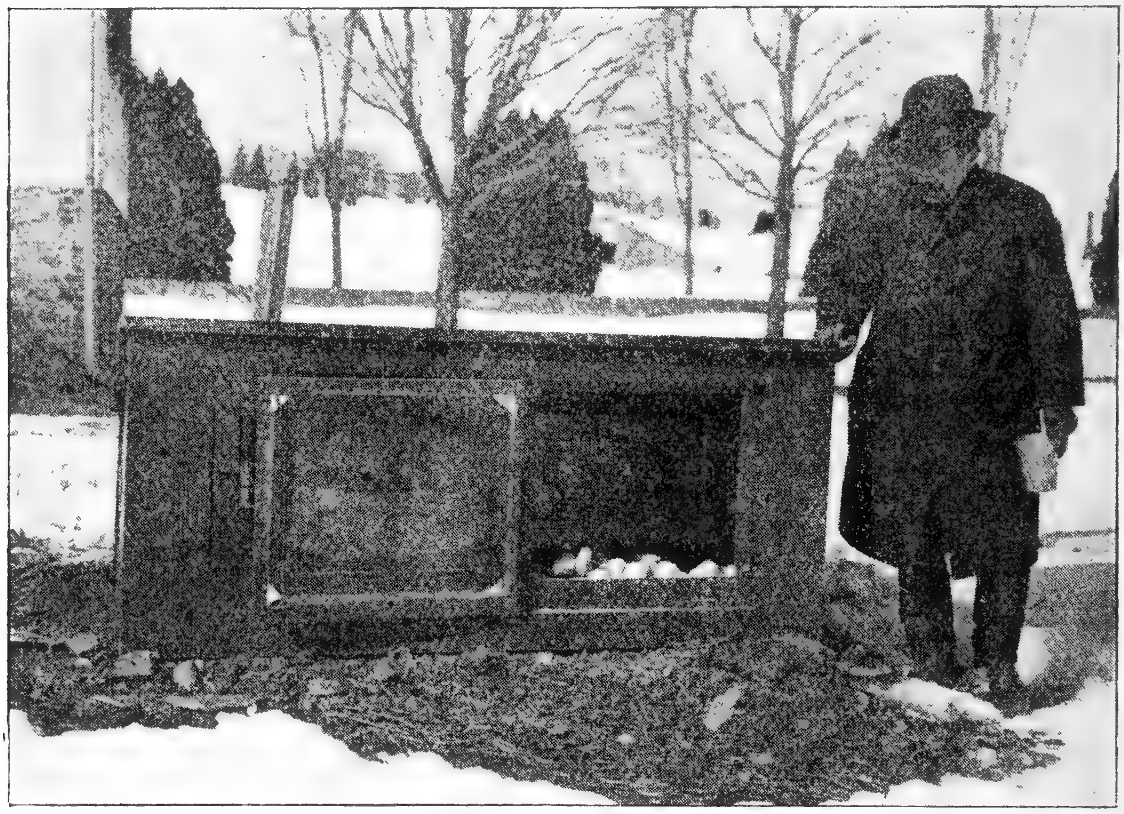

FIG. 13.—A brooder suitable for winter weather, as well as for summer.

when the snow is on the ground and the chicks necessarily confined, it may be wise to limit the number to twenty-five or thirty. Yet, if after the first two weeks the chicks can get out on the ground, fifty can be easily accommodated. By utilizing such means as have been described one may be sure of raising a few early broilers. If the future poultryman will only "go slow" and practice in a small way before taking up the work as a business, he will be in much better shape to compete in our markets, and failures in poultrydom will decrease fully seventy-five per cent.

Care of Young Chicks.—In order to have a good, early maturing pullet it is necessary that she get a good start. The first few weeks' care is responsible to a great extent for her success or failure eight months later. Feed, regularity of feeding, cleanliness, and plenty of grit and water are all important matters. Chicks should be carefully protected from storms and sudden changes of weather, since these together with the low vitality of the parent are responsible for more deaths than is improper food. Poultrymen differ considerably as to when the chick shall have its first food. Good results have been secured when chicks have been permitted to pick a little sand or fine grit from a clean board when about thirty-six hours old, and, when about forty-eight hours old, to eat bread crumbs moistened in milk and squeezed dry. After that almost any of the prepared chick foods may be fed about five times a day till the chicks are two or three weeks old, when they will do well on wheat screenings and need not be fed oftener than three times a day. It is advisable to let the chicks have access to green feed at all times. Fine clover hay, cut with an ordinary straw cutter, is excellent, and also makes a good litter to scatter the feed in. It is best, however, to give the last food at night on a clean board, letting the chicks eat all they will and then removing the board. At other times care should be taken that they be kept hungry, or at least sufficiently so to be eager to eat when fresh food is offered them.

FIG. 14 —A good brooder lamp costing less than fifty cents.

THE CAMEMBERT TYPE OF SOFT CHEESE IN THE UNITED STATES. See Bul. 35

INTRODUCTORY PAPER BY H. W. CONN, CHARLES THOM, A. W. BOSWORTH, W. A. STOCKING, JR., T. W. ISSAJEFF.

[Published jointly by the Storrs Agricultural Experiment Station and by the Dairy Division of the Bureau of Animal Industry, U. S. Dept. of Agr., Washington, D. C.]

INTRODUCTION.

[BY L. A. CLINTON, DIRECTOR STORRS AGRICULTURAL EXPERIMENT STATION.]

The investigations in soft cheese making were undertaken by the Storrs Agricultural Experiment Station with the hope that there might be developed a new industry especially adapted to New England conditions. The Camembert type of soft cheese seems especially adapted to home manufacture. The process of manufacture has, however, been held as a trade secret, and no source of information has been available for those who may have desired to make this type of cheese. A series of preliminary studies was undertaken and the results gave promise of a successful solution of the problems involved and demonstrated the value of the work.

COÖPERATION WITH THE DAIRY DIVISION OF THE BUREAU OF ANIMAL INDUSTRY U. S. DEPARTMENT OF AGRICULTURE.

The continuation of the investigations, however, involved a larger outlay than the means of the Station would permit. Recognizing the wide value which would result should the experiments prove successful and a new industry be established, a coöperative agreement was entered into between the Storrs Agricultural Experiment Station and the Dairy Division of the Bureau of Animal Industry of the United States Department of Agriculture, Washington, D. C. Under the terms of this agreement a thorough study is to be made of the problems involved in the manufacture of some of the types of soft cheese which are so popular in Europe, but which have been manufactured in this country only to a very limited extent.

The Storrs Agricultural Experiment Station has furnished the necessary laboratories, apparatus, and curing rooms for conducting the experiments, and has had the general planning of the work. The Dairy Division of the Bureau of Animal Industry has furnished three experts to assist in the work, viz.: a mycologist, a chemist, and a practical cheese maker, and has provided for certain traveling expenses connected with the work. The organization of the actual working staff connected with these investigations is as follows:

H. W. Conn, bacteriologist of the Storrs Station, supervisor.

Charles Thom, cheese expert of the United States Department of Agriculture, mycologist.

A. W. Bosworth, cheese expert of the United States Department of Agriculture, chemist.

Theodore Issajeff, cheese expert of the United States Department of Agriculture, cheese maker.

W. A. Stocking, Jr., assistant bacteriologist of the Storrs Station.

In addition to the above who have been actively engaged in the cheese investigations, credit is due to Dr. B. B. Turner, chemist of the Storrs Station and of the Connecticut Agricultural College for valuable suggestions, and to Mr. W. M. Esten, laboratory assistant to Dr. Conn for bacteriological determinations. The Connecticut Agricultural College has freely permitted the use of laboratories and apparatus for this work, without which we would have been seriously handicapped.

The work is now thoroughly organized and the investigations are being conducted with the following objects in view:

1. To learn the details of the methods of manufacturing some of the soft cheeses.

2. To learn more accurately the details of the process of ripening and to determine the organic agents involved and their exact functions.

3. To study the chemical composition of the ripened product, the changes involved in ripening, and its relation to food values and digestibility.

4. To discover the difficulties connected with the manufacture of soft cheese and the ways of meeting them.

5. To learn whether the manufacture of a first-class product is possible in the United States.

6. To make public property of all useful and desirable information upon the subject of the manufacture of soft cheese.

This bulletin is necessarily preliminary in its nature, but it will be followed shortly by others dealing specifically with the problems involved in soft cheese making and how to solve them.

CONCLUSIONS.

The conclusions we have drawn at present are as follows:

1. The ripening of Camembert cheese is due to the presence of definite molds and bacteria, not a matter only of manipulation and locality.

2. One mold (Penicillium candidum?) produces the principal changes in the curd which gives the texture of the normally ripe cheese; another, Oidium lactis, acting in conjunction with the first produces the flavor.

3. The presence of lactic bacteria (commonly used in the form of a starter) produces the necessary acidity of the curd and prevents further bacterial action within the body of the cheese.

4. No other organisms seem absolutely necessary to produce the texture and flavor of the Camembert cheese, though other species of bacteria are always present in or on the cheese.

5. It is possible so to control the process of ripening as to produce such results with reasonable uniformity.

6. It is perfectly practicable to produce first-class Camembert cheese in America.

SOFT CHEESES COMPARED WITH HARD CHEESES.

Hard cheeses have for a long time been well known in this country and have been manufactured by our dairymen in large quantities. Until recently little has been heard concerning another type of cheese properly called soft cheese. This last type, although made from curdled milk, requires very different methods of manufacture, and when ready for the table is a totally different product. As the name indicates, the cheese is

softer, frequently so soft as to be readily spread upon bread like butter. But in addition to this there are other striking differences between the soft and hard cheeses. The soft cheeses are smaller than most of the hard cheeses. They do not keep well. Above all, their flavor is quite different and is usually much stronger. It is a well recognized fact that while cheese is a valuable food because of the large amount of protein it contains, nevertheless it owes its chief popularity to its flavor. Flavors are known to be physiologically necessary to the proper digestion and assimilation of foods. Hence the value of highly flavored foods which give relish to those coarser and less flavored, can hardly be overestimated. The soft cheeses, with their strong flavors, so thoroughly enjoyed by some people, have, therefore, a value decidedly their own.

The primary difference between the hard and soft cheeses is due to different methods of manipulation of the curdled milk. In the hard cheeses (Cheddar, Swiss, American, Edam, etc.) the milk is curdled rather rapidly and the curdled mass subsequently cut into small pieces to allow much of the whey to separate from the curd. Sometimes the curdled mass is heated still further to separate curd and whey. After this the curd is placed in frames and subjected to a high pressure that forces out more of the whey, leaving a very hard mass of tolerably dry curd. Such a curd ripens slowly and is not ready for market for some months, and even when perfectly ripe it preserves its form and never becomes very soft.

The soft cheeses (Camembert, Brie, Isigny, Limburger, Backstein, Neufchatel, Cream cheeses), although each is made in a special manner, all agree in one point. The whey is never fully drained from them. The curdled milk is commonly ladled into forms and allowed to drain naturally. They are not subjected to pressure or heat and they therefore contain a larger per cent. of water at the start than the hard cheeses. As a consequence of their high water content and soft texture various micro-organisms find in them favorable conditions for growth and enzyme action also occurs more readily than in hard cheeses. The action of these two groups of fermentation agents ripens the cheeses rapidly and develops high flavors. The cheeses are ready for the table in a few weeks instead of months, and when ripened have not only strong flavors but

frequently very penetrating and more or less offensive odors, as in the well known Limburger cheese. Because of the rapidity of the chemical changes going on in them these cheeses are more perishable than the true hard cheeses. Their marketable period is very short. If placed upon the table at just the right period they are very appetizing. If insufficiently ripened they do not have the proper flavor or texture, and if even slightly over ripened they rapidly show a tendency to decay and are soon ruined. To place them on the market in such a way as to reach the consumer's table at the proper stage of ripening is one of the difficult problems of the industry.

THE MARKET FOR SOFT CHEESES IN THE UNITED STATES.

The home of these cheeses is continental Europe. No part of Europe is without its types of soft cheese. There are several general types, like Limburger, Camembert, and Brie, that are widely distributed and made in different countries, and there are in addition many local varieties with a narrower reputation. From their centres of manufacture they are exported to various cheese consuming countries, so that all of the chief types are found generally in the various parts of Europe. Importations of soft cheeses to the United States have not been very large. The American market in the past has been almost monopolized by the hard cheeses, principally of the type of the English Cheddar. Americans have known little of the great variety of soft cheeses common in European markets and there has consequently been very little call for them. Within the last generation a moderate demand for soft cheeses has been developed. This demand may be attributed partly to our increasing foreign population and to the desire of people of European birth for the types of cheese familiar to them at home. It is also partly due to the taste acquired by Americans who have traveled abroad, as well as to a growing appetite for them among others who have tried the new delicacies. This has led to the importation of several varieties of soft cheese to satisfy a market which is increasing every year. This importation has reached about a million pounds with a value of about $150,000 per year.

There are many reasons why the total importations have not been greater. It is difficult to import the more delicate

varieties in prime condition. Two weeks is the shortest period possible between leaving the factory and reaching the retail market in America. If fully and properly ripened before shipment these two weeks cover almost the entire marketable period of the cheese. To reach our market in condition for use at all, they must be packed and shipped before they are in condition for the table. In practice some are shipped before they are half ripe or even when the ripening has just begun. The change of conditions and entire lack of care in transit makes the resulting cheeses which reach our markets of very uncertain quality. It is also difficult for the casual buyer to determine when the cheese is really ripe. These irregularities furnish good reasons why such importation is discouraging to dealer and to consumer alike.

On the other hand, these conditions have stimulated the production of certain soft cheeses in America. Particularly is this true of Limburger cheese for which there is a large demand. It has been found not difficult to manufacture, and it is now made in this country in a number of places with a considerable degree of success. In response to a similar demand a considerable business has arisen in the manufacture of the forms sold in our market as Brie, Isigny, Wiener, lunch, miniature, etc., all of which though sold under all sorts of trade names, have a common type of ripening. Although the details of form and making vary with the factory, the brand, and the season, these may be grouped together perhaps as the "American Brie" type. This American Brie type must not be confused with the French Brie type, for the latter is quite a different product. These American types have made for themselves a large market and may be regarded as a fairly well established product. A preliminary study of their ripening process and the factories in which they are produced indicates, however, a very unsatisfactory condition. The ripening is so little understood and results are so uncertain that one maker admitted that after the cheese is made the flavor of the product is practically an accident over which he has no control. Some of the cheeses are ruined in the ripening and the factories that make them lose considerable of their product. It is evident, therefore, that the manufacture of the American type of these cheeses can hardly be regarded as a success until some means of controlling the ripening can be

devised that shall reduce the failures and give a more uniform product. Moreover, the American type of cheeses is quite different from the French cheeses. It is stronger, has a more unpleasant odor and a less delicate taste. The delicate tasting Brie and Camembert cheeses are mostly imported from France. Up to the present time, their manufacture has been successful in but few places in America, and there is a general belief that their manufacture in this country is impossible.

Another indication of the growing popularity of soft cheeses is the large demand for the varieties sold under various brands as Neufchatel and cream cheese. The basis for most of these is the common "Cottage" or "Dutch" cheese, and many of them are merely sweet or sour curd put in an attractive and appetizing form. The manufacture of these varieties is comparatively simple with practically no danger of loss. They are sold and eaten when fresh. Further, they will yield a larger amount of salable cheese from the same quantity of milk than any other varieties and bring prices almost as high as the best imported cheese. Very naturally these cheeses form the basis of a profitable industry. But here, too, we find that the common American product is different from the cheese in Europe going under the same name. The Neufchatel cheese of Europe is usually a ripened cheese, but the cheese going by this name in the United States is usually unripened curd with an attractive wrapping. Some of these American products, however, are highly flavored and compete favorably with certain ripened types that are imported. All of them command a far higher price than the ordinary hard cheese.

It is certain, therefore, that there is an established and rapidly growing market for the best types of soft cheese. The profit in the manufacture of the hard types of cheese is exceedingly small both to the factory and to the producer of milk, but the prices of the highest class of ripened cheeses (40 cents or more per pound) are so much higher than the prices of the hard cheeses that the introduction of their manufacture should be a great benefit to the dairymen. The fact that soft cheese will not keep very long gives an especial advantage to the domestic over the foreign producers if the products can be made of equal merit. For such perishable products there is a great advantage in an intimate relation between the maker and the consumer.

Factories near enough to a large city to supply the demand with cheese always ripened to exactly the prime condition, should easily be able to control their home market if they can once control their product. It seems possible that there will be an advantage, nearer the small cities at least, in their production by individual dairymen who could dispose of their own product in a restricted market.

The great difficulty in the way of the successful development of the soft cheese industry is in the difficulty of controlling the ripening so as to produce a uniform product. Even in the localities where these cheeses are made in Europe their treatment seems to be purely by "rule of thumb" methods handed down as a result of more or less successful experience, rather than to involve an actual knowledge of the reasons for the various steps in the process. As a natural consequence the results are to a large degree irregular and utterly unexplained failures of every kind are at least very familiar. Recognizing the difficulties in their manufacture in Europe it is not strange that the troubles increase when attempts are made to transplant such industries into a new country, where the practicable rules applicable in the old locality are vitiated by new sets of conditions, in atmosphere, temperature, flavors of milk, and other factors. So great have been these troubles that there is a belief that the American product cannot be made equal to the imported. It is said that the difference in food which the cows eat produces a differently flavored milk, thus making domestic cheeses flavored unlike those imported. Whether this be true or not it is certain that little success has been reached by American makers in trying to reproduce the higher, more delicate grades of European soft cheese. When they have succeeded it has been by importing their help from Europe, and in these cases the makers have carefully preserved their methods as trade secrets. Even in the successful factories many failures occur. Little attempt has been made apparently, and no successful attempt to overcome the new difficulties arising in the new conditions. As a result the home product has commanded an inferior price and is less esteemed than the imported cheese. For this reason the American makers have disguised their goods by French labels, and have not tried to make a market for an American product. The market varieties show great irregularities. Com-

plaint is constantly made by the dealer, and consumer as well, that common brands of some of the soft cheeses are utterly unreliable. In the purchase of a cheese, except by an expert, it is little more than a lottery whether it will be mostly a sour curd or might be eaten through a straw. It is clear then that although there is a good market for uniform and reliable goods, radical changes must be made in the methods of production before these soft cheeses will obtain the large place in the American market which their real merit deserves. For the American dairyman the development of this almost new industry well deserves consideration. It is true that more difficulties are involved in the manufacture of the soft than of the hard cheeses, but the returns are correspondingly greater and quicker. Experience, however, in other lines of dairy work shows that thorough scientific study of the conditions, the problems, and the results sought, is rewarded by the development of successful practical methods of controlling the entire process. The soft cheese will be shown to be no exception to this rule.

CAMEMBERT CHEESE.

Camembert cheese was selected as the first type of soft cheese to be studied, for several reasons. It is one of the most delicate and expensive of the soft cheeses, selling on the market usually for 40 cents a pound. It has been successfully produced by but one large factory in our eastern states. A few other factories have made cheese called "Camembert," but their product has not made for itself a place in our market in competition with the imported varieties. The marketable period of this cheese is so short that the domestic brand should have a great advantage over the imported. The shortness of the ripening period—4 to 5 weeks—together with its high price, insures a good return upon the investment and commends its manufacture to the dairyman located too far from the city to sell his milk as milk. Camembert cheese is already sufficiently well known in this country to insure the ready sale of any brand which shows itself to be always reasonably reliable. Considering the lack of uniform quality in the Camembert cheeses seen on sale in half a dozen of the large cities of the United States, the wonder is not at the smallness of the

demand, but that the people will continue to buy it at all. Inquiry shows that many people are fond of the cheese but never buy it because they cannot depend upon the product. Dealers do not like to handle it for the same reason. The fact that local demand compels grocers in cities, often against their will, to handle such cheeses is evidence that a really good and reliable Camembert cheese would make for itself a large market. It is readily seen, therefore, that the making of this cheese offers good possibilities of return to a large number of dairies or factories each to supply a limited territory rather than an enormous return to a few large concerns. That it requires special study to overcome the difficulties of its production before it can be made by the general dairyman is also evident. For these reasons Camembert cheese seemed to offer a most useful problem.

When we started the work it was impossible to secure at once a cheese maker who was familiar with the factory manipulation in the manufacture of these cheeses. We were therefore, obliged to work from vague and inadequate descriptions of the details of making published in European journals. Practically no detailed description of the practice of the best factories was to be found, while the few scientific papers available scarcely touched the practical problems. Our problem was to imitate a market type without any personal knowledge of how it was produced. The most extended scientific work that had been published was that of Epstein (Archiv f. Hyg. Bd. 43. pp. 1–20, Bd. 45, pp. 354–376) who made a somewhat careful study of the bacteria and molds found in a series of ripe Camembert cheeses and endeavored to determine which were the agents of ripening. The conclusion reached was that the ripening of Camembert cheese is produced by the agency of bacteria alone, although he also concluded that the ripening of Brie cheese, which is almost identical with Camembert, is aided by a mold.

In opposition to this, there have been published the results of the work of Roger (Sep. pub. Soc. Fran. d'Encore. l'Ind. Lactiere, 1902, and Revue Hebdomadaire 11, pp. 327–343) who has also studied the organisms concerned in the manufacture of Camembert. He has reached the conclusion that ripening is produced by the combined agency of a mold and at

least two different species of bacteria. Roger's work has the merit of having been practically applied to the manufacture of Camembert cheese with results which he claims have been very satisfactory. But, on the other hand, Roger has given the public no evidence of the work he has done to reach his conclusions. He has preferred to develop the practical side of his studies as a trade secret, and has therefore in his published articles withheld all details of his experiments and descriptions of his molds and bacteria. Consequently the published account of his work is less useful than that of Epstein. Neither worker has given sufficient data to demonstrate his claims or practical methods of beginning experiments upon cheese making.

The fact that the conclusions of Epstein so totally disagree with those of Roger suggested that the subject at all events demanded further and more thorough investigation. Moreover, it will be seen in the following pages that our own results in a large measure differ from those of both of these investigators, for we have been able to produce Camembert cheese, typical both in flavor and in texture, by a method involving organisms essentially different from those claimed by Epstein or Roger as the cause of ripening. It is scarcely possible that the details of either set of experiments can be all mistakes. The fact that three series of studies upon the same subject have reached three quite different results indicates one of two things. Either the cheeses used in the three different series of experiments have been really different types, though under the same name, or a very similar final product may be produced by different agents. Possibly both of these explanations are needed to account for the discrepancies. Certain of our experiments have yielded information which yields to the belief that each of the three lines of experiment has brought out part of the truth. These results will be discussed in detail later. There is good evidence also that more than one type of cheese reaches the market under the name of Camembert. All of them have sufficient similarities in texture and appearance to lead to classing them together, but in flavor and odor they show marked differences. Camembert cheeses secured from different regions show much variation. The study of the brands offered for sale in several cities emphasizes an entire

lack of uniformity among them. The stage of ripening makes a marked difference in their appearance. One can find upon the same counter cheeses in which ripening has barely become distinguishable mixed with those in every stage of fitness and unfitness for use, even to those which are absolutely putrid, and all are likely to be sold as in prime condition for the table. Such cheeses on the surface may be whitish or grayish in color, or yellowish to reddish and may be dry or sticky with the accumulation of bacterial growths. They may be practically odorless or at least inoffensive to smell, or they may emit very objectionable odors. These differences are not due wholly to the degree of ripeness, for cheeses with very different appearance are often found of the same texture and flavor within. Moreover, cheeses with almost identical surface appearance often differ decidedly in texture and flavor. The external differences we have learned are due chiefly to the different kinds of micro-organisms that grow on the outside of the cheese, some of which are quite unnecessary to the production of the desired ripening. Consultation with dealers shows that there is no accepted ideal among them for Camembert cheese, but they disagree constantly on such matters. There also appears to be confusion in many quarters between the types known as Camembert, Brie, and Isigny. This is probably due to the fact that the imported Brie is ripened in very nearly the same way as Camembert, differing only in size and shape and details of making, while the type we have discussed as American Brie, which includes the cheeses sold as Isigny, is very different in its appearance and ripening process, as well as texture and flavor. It has been shown that certain makers use these names as practicably interchangeable, *i. e.*, regard them as the same general type of cheese moulded at different sizes, and marketable at different degrees of ripeness, and sometimes the same cheese exactly is sent to market bearing different labels.

The true Camembert type of cheese is that imported from France. These are shaped so that they fit wooden boxes about four and one-half inches in diameter and one and one-half inches thick. Upon the removal of their wrappings, the cheeses usually have a rather firm rind about one eighth of a inch thick composed of interlaced fungous threads supporting dried cheese. Within, the ripe cheese should be a yellowish cream color of a

waxy or creamy texture often almost liquid in age, and with a distinct characteristic flavor that is often not present in American types even though they are labeled Camembert.

The first problems which we undertook to study were scientific rather than purely practical. The reasons for this were two. First, we were unable at the beginning of our work to secure a cheese maker familiar with the factory methods of making and curing this type of cheese. Second, it was not our purpose merely to imitate the methods in use in producing this cheese in France. This would have been hardly worth while unless we could obtain a thorough understanding of all the principles involved. It was desirable therefore at the outset, to conduct a series of experiments which would bear directly upon the determination of these principles, and this could be best done by making a few cheeses under controlled conditions. In this way we reached conclusions upon the problems involved which stood the test of practical experiment and which led quickly to successful results when cheese making was actually begun. After securing the services of Mr. Issajeff we began the application of our scientific studies to the practical question of cheese ripening. No description of the practical method of making and caring for these cheeses will be given in this introductory paper. These will be given in a later bulletin to follow shortly. It will be understood, however, that the manufacture of Camembert cheeses is being now actually carried on at the Storrs Experiment Station, and that the scientific results given here have been actually applied to the process of manufacture.

RIPENING OF CAMEMBERT CHEESE.

A brief outline of the ripening of Camembert cheese is as follows: The rennet curd is first ladled into forms, filling them up to a depth of about five inches, and is allowed to stand for several hours for draining. During this time the curd settles until it reaches a thickness of about two inches, when the cheeses are turned and allowed to stand in the forms. During the next twenty-four hours the curd settles still further, reaching a thickness of one and one-half inches. The first change affecting the ripening is the souring of the curd which begins while the cheese is in the forms. In the course of two days the curd has become hard and sour. They are then removed

to the ripening cellar. After a few days in the cellar the molds begin to grow upon their surface. From this time until the end of the ripening period there is little visible external change in the cheese, except in the luxuriant growth of molds and in the fact that during the later stages of the ripening there commonly appears upon the surface of the cheese a brownish red growth which is likely to be moist and slimy. This brownish red growth has been regarded as a necessary factor in the ripening of cheese, but whether it has any necessary connection with it we are as yet uncertain. During the ripening the cheeses at first become somewhat hard and resistant when pressed with the

FIG. 14.—An improperly ripened Camembert cheese; the outer portion is liquefied, while the center is hard, sour curd.

finger. Later they soften noticeably and when they approach ripeness they are quite soft and yield readily to the pressure of the finger. The ripeness is determined chiefly by the softness to the touch and is easily told by experience.

The ripening changes are studied by cutting sections of the cheese at various stages. The photographs show such stages of ripening, of which a brief epitome is as follows:

After about two weeks the acidity of the curd begins to be noticeably less, especially at the surface, and as the ripening progresses the acidity in time disappears as far as indicated by

the test with litmus paper. Meantime a change in texture of the curd is evident to the eye. Beginning at the outside there appears a change of the hard curd into a somewhat softer, waxy material. This layer of waxy cheese, beginning at the surface,

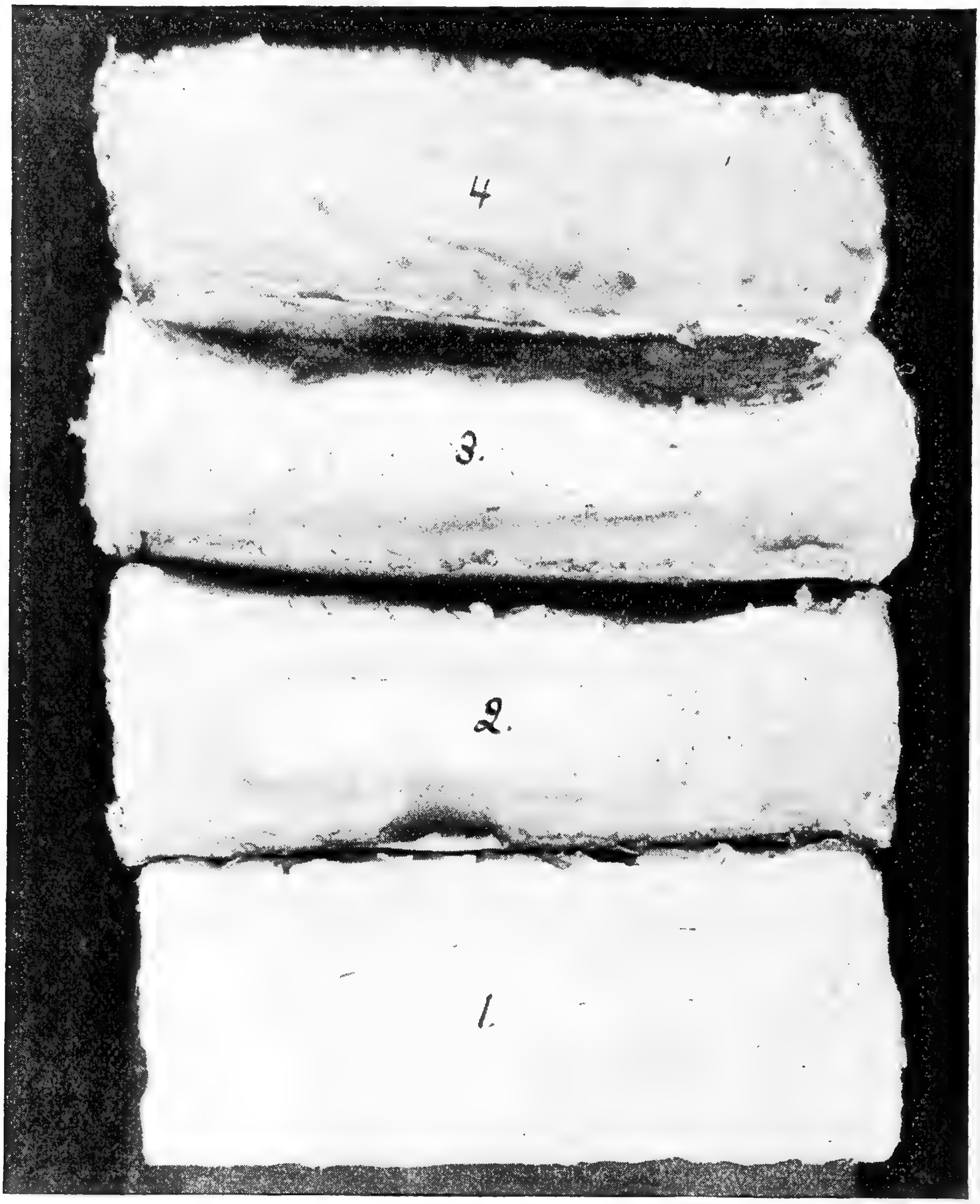

FIG. 15.—A series of Camembert cheeses.

1. Unripened cheese.
2. Half ripened cheese with well developed moldy rind.
3. Cheese two-thirds ripened, but with central mass of hard curd showing gas holes.
4. Cheese nearly ripe, and so soft that the upper edge moved from its own weight during the exposure.

slowly extends toward the center and in the course of four or five weeks should reach the center. In half-ripened cheeses there will be found a layer of softened consistency on the outside, with a central mass of acid curd within, which has not yet been affected by the ripening agents. When the cheese is completely ripened the softening extends to the center and the whole cheese, from the outside to the middle, has assumed a consistency of moderately soft butter. When in prime condition the cheese is soft enough to spread upon bread or crackers, but not soft enough to run. An over ripened cheese, however, becomes still softer until in time the whole interior of the cheese below the rind is converted into a nearly liquid consistency, which will run out of the cheese readily if the rind is broken. On the other hand, an under ripened cheese will show more or less of the sour curd in the center which has not been affected by the softening agents.

The cheeses purchased in the market are very frequently in one of these two conditions, over-ripe or under-ripe. (See Figs. 14 and 15).

During the ripening process there appears a peculiar flavor which is characteristic of this type of cheese. The flavor is sometimes not noticeable until the cheese is nearly ripe, so that a cheese which is two-thirds ripened may lack the flavor in question. The final result is a cheese with a firm, moldy rind, and with the contents uniformly soft to the center, and possessing a characteristic, piquant flavor which is found in this type of cheese only.

The problems have been to determine the causes of the phenomena of ripening, and these are manifestly three:

1. The cause of the original souring of the curd.

2. The cause of the decrease in the acid and the gradual softening of the curd.

3. The development of the flavors.

SUMMARY OF SCIENTIFIC INVESTIGATIONS.

Our work has been developed along three scientific lines. The results of each line of study will be summarized here, and the detailed accounts will follow in separate papers.

MYCOLOGY.

The constant appearance of mold in or upon soft cheeses such as Roquefort, Camembert, and Brie, has been referred to already. The works of Epstein and Roger already discussed give two views of their relation to the production of cheese. Epstein believes the mold entirely unnecessary in the production of Camembert, but notes its presence and important function in the ripening of Brie. Roger, on the contrary, believes the mold to be really essential in the ripening of Camembert. Other investigations published, record the constant appearance of mold upon Brie, but give little or no information with reference to Camembert. Popular descriptions of Camembert cheese factories, however, describe the constant presence of a special mold in the ripening cellars. The references to molds in the literature of the subject and their constant presence upon the cheeses, fixed for us a series of questions. What molds are associated with Camembert cheese as found in the market? Which, if any of these, are essential to its proper ripening? Exactly what changes in the ripening process result from fungous activity? What molds are deleterious and what is their action?

With these questions in mind we first made a cultural study of the floral of the Camembert cheeses found in the American market. In this about twenty molds were soon found, isolated in pure cultures and described. A more careful study of our cultures with a comparative examination of the surfaces of the different kinds of cheese showed that only a few of these molds were really common, while but two of them were always present.

With the organism once in pure cultures we next undertook to determine what relation, if any, each might bear to the ripening process. Since it is practically impossible to make cheeses entirely free from other molds, or bacteria, or both, without changing its chemical nature, some controlled means had to be devised to study the various agents of ripening and the steps of the process. We found it necessary to limit this comparative study to the effects of a small group of molds. These were grown in pure culture under known conditions upon milk, casein, curd, cheeses, and special media in order to determine separately different phases of the physiological action of the molds. For this study we used 1, the one we shall call the

Camembert mold (Culture No. 128); 2, the related species isolated from Roquefort cheese which we may call the Roquefort mold; 3, one species of Mucor; 4, Oidium lactis, and sometimes other species of the same genus Penicillium. In some studies the list has been extended to a dozen species in each experiment, because with the larger numbers, comparison of characters gives a better judgment of the real nature of the processes studied.

The souring of the curd as a consequence of the presence of lactic bacteria has already been described as the first change after the cheese is made; also the fact that in Camembert cheese the lactic acid so produced later largely disappears, so that when fully ripe such a cheese commonly has an alkaline reaction to litmus. This disappearance of acid together with the well-known ability of many molds to reduce acidity, has been regarded as the main, if not the only, function of the mold in ripening cheese. This view has been widely quoted. Comparative cultures of a large number of species shows that a very large proportion of the common molds are able to neutralize, if not decompose, lactic acid, but they do this in different degrees and at very different rates. The Camembert mold increases the acidity of the medium during its first few days of growth, then changes and reduces acidity for the remainder of the period of activity. Some other forms reduce acidity from the first and do it much more rapidly than this one. If this were the only function of the mold in cheese ripening, many other species should be equally valuable, or by working more rapidly, would probably be far more effective. This part of the ripening then might be accomplished by any one of a large number of forms.

We then turned our attention to determining whether any or all of these fungi acting in pure cultures possessed the power to change the hard curd to the semi-liquid or viscous condition of the ripened Camembert cheese. A long series of cultures upon sterilized milk, milk agar, and sterilized curd were prepared. Careful bacterial determinations were made to show that the cultures were pure. From these the following facts appeared: Sterile milk is slowly but almost completely digested by nearly every species of fungus tried. Flakes of curd in milk agar plates disappear as a result of the action of the fungi selected

for this experiment. Masses of curd put in flasks and sterilized in the autoclave until they seemed almost the texture of rubber, became nearly completely soluble in water after four to six weeks' action of either the Camembert or Roquefort mold. Experimental cheeses made from time to time with the addition of large quantities of "lactic starter," to exclude other bacteria, were inoculated with this mold and carefully kept pure in bell-jars. Under favorable conditions such cheeses assumed the *texture* of ripe Camembert cheese in from three to five weeks. Repeated analyses have shown that this is approximately the same kind of digestion as is found in the ordinary Camembert cheese. These pure culture experiments have thus shown that this species of mold possesses the ability to change the texture of curd to the texture of ripe cheese in the period of time recorded by the makers of such cheese as necessary for the ripening of Camembert.

How, then, is such a result accomplished? Johan Olsen in describing the Swedish "Gammelost" declares that "He who eats Gammelost eats truly more mold than cheese." In other words, he believes that in its ripening process the changes are due to the complete penetration of the cheese by fungous threads which act directly to change its character. Gammelost would then be fungus flavored with cheese. But cultural studies and careful microscopic examination of hundreds of sections from a number of different Camembert cheeses show that our problem is very different. In Camembert cheese the mold forms a felted mass of hyphae upon the surface and penetrates perhaps one-sixteenth of an inch into the curd. It never reaches even one-third of the distance to the center of the cheese, while its spores are borne only upon the surface. This, together with a very thin outer layer of curd, constitutes the rind of the cheese.

Further, our experiments referred to above show also that on sterile milk the mold forms colonies floating upon the surface only, while a mass of curd in the bottom of the tube, fully two inches away from the nearest fungous thread, may still continue to be digested. It is clearly impossible to attribute these marked digestive effects at such distances to the direct action of the fungous threads upon the medium. From similarity to other known processes, the presumption arises that these are the result of the secretion of enzymes by the mold.

To test the validity of this hypothesis a set of cultures were grown for a long time on Raulin's fluid, then examined by the chemist. The presence of an enzyme capable of digesting proteid was satisfactorily demonstrated. We have, therefore, shown by pure culture methods that the Camembert mold (Penicillium candidum?) is not only capable of changing the acidity of the curd, but is able also to cause such changes of the curd as will account for the texture of the ripe cheese and that this result is due to the secretion of an enzyme.

A cheese ripened by this mold alone is white, soft, creamy, and entirely palatable, but is wanting in color and completely lacks the peculiar flavor for which Camembert cheese is sought in the market. After repeated tests had shown the same result, we began to seek for some other organism capable of producing the desired flavor. The discovery of this flavor in certain experimental cheeses at this time was followed by their immediate microscopic examination which showed the presence of the second of the two fungi originally found on Camembert cheese. This mold, the well-known and universally distributed *Oidium* (or *Oospora*) *lactis* had been discarded from much of our work on account of some failures and objectionable results. We now found that the inoculation of this organism upon cheeses partially ripe and lacking flavor would lead to the production of the flavor distinctly in a very few days. Although from its habits of growth its development upon cheese is nearly always accompanied by rapid multiplication of bacteria, this seemed good circumstantial evidence that Oidium lactis has something to do with the flavor of Camembert cheese. Additional evidence is found in the fact that the examination of properly flavored ripe cheese of our own make and from the market has never failed to show the presence of Oidium lactis, and it has never been shown to be present upon ripe cheeses without the flavor being present also. The great difficulty surrounding complete proof of the agency of a particular organism in producing flavor lies in the fact that the flavors do not begin to appear until the acidity of the curd is much reduced and the digestion attributed in our work to the Penicillium has advanced considerably. Flavors, the chemists tell us, are associated with the "end products of digestion." When ripening has reached such a stage as to permit flavor formation, the growth

of Oidium upon the surface of a cheese usually becomes complicated by the development of surface bacteria which becomes possible at about that time on account of the reduction of the acidity. A final conclusion as to whether or not Oidium lactis alone produces the flavor will depend upon an exhaustive test of those bacteria so constantly associated with it. The bacteriologists, as will be seen later, have shown that few bacteria except lactic species are found within the cheese and none of them seem able to produce flavor. The production of flavor by bacterial action would then depend entirely upon such bacteria as might grow upon the surface of the cheese. In addition to the evidences already mentioned it is found that a cheese entirely covered by a good growth of the Camembert mold evaporates water rapidly and develops a hard, dry rind, so dry as to obstruct the entrance of bacteria from without. In certain of such cheeses, into which Oidium was inoculated at the time of making, the characteristic flavors finally appeared without the association of the reddish slimy surface so commonly seen. Further many cheeses made and ripened entirely without Oidium lactis have in their later stages become covered with bacteria which produced the surface appearances so often described, but failed entirely to develop the typical flavor. In the light of the bacteriological proof that the interior of the cheese is practically a pure culture of lactic organisms, the production in some cases of both the flavor and texture of properly ripened Camembert cheese without a rich surface growth of bacteria, is very good circumstantial evidence that Oidium has some function in producing the flavor.

A cheese inoculated with Camembert Penicillium will not begin to show delicate white threads of mold for about three days. The mold develops rapidly from that time until by the tenth day (sometimes by the seventh or eighth) the cheese is usually covered entirely by a pure white cottony mass of threads forming a layer possibly one-eighth of an inch deep. With the ripening of the spores or conidia the color gradually changes to a greenish gray. This change is completed during the third week usually, and no growth seems to take place afterward. During the later stages of mold growth large drops of water are excreted by the mold and evaporate from the surface. The mold therefore has a rather definite period and course of

development. During that time it seems to be so thoroughly adapted to thrive upon cheese as to exclude almost every other form, but after its cycle of development is complete, it may be followed by other species which, if present before, are held in check by the more vigorous species.

One more phase of the mold problem perhaps belongs in this preliminary paper. Efforts have been made to find whether it is possible to substitute other varieties or species of the same genus of fungi for the one we have been using. For such studies the mold of Roquefort cheese has been carried as a check upon our work in numerous experiments. One other variety of Penicillium differing only in that it never changes color, but remains pure white, has been tested. Cheeses have been made with these three and several other related species. The Roquefort Penicillium grows strongly and rapidly upon cheese but its presence always causes a bitter taste which remains pronounced during the period of four or five weeks necessary for the ripening of Camembert. So strong is this effect that the presence of a colony of this mold less than an inch in diameter may often be detected by the taste of the cheese two inches away. The pure white Penicillium in its ordinary reactions to culture media seems to be identical with the Camembert mold, but when tested upon over one hundred cheeses, produced a texture so entirely different from the other as to make the product entirely worthless. It seems most surprising that two forms, so closely related in structure and in every reaction studied, should produce such different results in cheese ripening. Several other forms have been tried. Some produce pigments which discolor the cheese. Some produce bad flavors. A set of four species although allowed to grow for a period of six weeks, produced no softening of the curd. In two of these cheeses especially it was found that the curd was still sour and little changed less than one-fourth of an inch below the colonies of the fungus. The four cheeses used in this experiment belonged to a set of twenty, sixteen of which ripened readily in the ordinary way. Sets of cheeses made from the same milk and treated alike ripened quite uniformly as a rule. Of this set, sixteen ripened in the usual manner when acted upon by Camembert Penicillium. Four inoculated with other Penicillia refused to soften. Such a result shows that neither the molds used nor the bacteria and

enzymes otherwise present were capable of producing the texture of Camembert cheese in four cheeses of a series, the remainder of which were readily ripened normally.

BACTERIOLOGY.

The universal presence of bacteria in all dairy products suggests, of course, that they may play an important part in the ripening of our cheese. In the various scientific accounts of Camembert cheese bacteria are always mentioned, and both Epstein and Roger attributed to their action a considerable part of the ripening and flavor production. Our own preliminary studies of the market cheeses always showed the presence of bacteria in great number and in considerable variety. It was manifest that most of these were purely incidental organisms not contributing at all to the ripening. In the study of these bacteria the following questions have been kept in mind. Which kinds of bacteria are always found and which are only occasionally present? Which kinds of bacteria are present in fresh cheese? Which kinds of bacteria grow during the ripening? Do any of these bacteria produce the Camembert flavor? Do the bacteria contribute to the chemical changes that occur during the ripening? Part of these questions we have already answered, but part of them require further study.

We first made a bacteriological study of a considerable number of ripened cheeses, isolating all species of bacteria that could be found. Except that lactic bacteria were always found, this work gave no significant results. We were somewhat surprised to find that the group of bacteria that digest proteids (*i.e.* liquefiers) were commonly entirely absent. We had anticipated finding them in large numbers, inasmuch as the cheese is so evidently a digested product. This absence in large numbers suggested that the digestive agent must be looked for elsewhere than in bacterial action.

Our search for a flavor-producing bacterium has thus far been equally unsuccessful. Epstein states that by inoculating into a casein solution one of the bacteria he isolated from Camembert cheese, he obtained a typical flavor. We have been unable to find such a bacterium. We have carefully studied the action upon milk of the organisms isolated from cheeses in the hope of finding a flavor-producing bacterium, but have thus far

been unable to find one. We have, however, found bacteria that produce flavors that remind us of the American Brie, and of other flavors associated with some samples of cheese, but none that give the typical Camembert flavor. We are at present inclined to think that this flavor must be sought in some other line as has been shown in the previous pages.

The study of the growth of bacteria in the cheese during the ripening is very interesting and significant. We have studied this problem in cheeses made with and without a lactic starter. The cheeses made with a lactic starter are more uniform in ripening. Experience has shown that we can with greater certainty obtain a first-class cheese if we use such a starter. For this reason the study of the bacteria in such cheeses is especially significant. The results are very simple for they are an exact repetition of what occurs in souring milk as has been already shown. (Conn and Esten, Rep. Storrs Sta. 1901–2.) At the outset there is commonly a small variety of bacteria present, which develop for a short time. But in a few hours the lactic bacteria get the upper hand and all other species practically disappear. After about two days the cheeses contain a practically pure culture of lactic bacteria. These increase in numbers until they are about 900,000,000 per cubic centimeter, and remain at about this number during the ripening, somewhat falling off toward the end. In these cheeses there is no growth of liquefying bacteria to which might be attributed such digestive action. There are commonly a few of these at the start but they never multiply so that they become abundant enough to lead to the supposition that they are likely to play any part in the ripening. Moreover, as mentioned above, the ripening of these cheeses proceeds from the surface inward, a fact that indicates that the ripening agents are chiefly or wholly on the surface.

These facts are rendered more significant by the bacteriological study of one set of twenty cheeses that were made without lactic starter. In these cheeses the lactic bacteria never obtained such a complete ascendency over the other species as where a starter was used. While they became very abundant we found that certain liquefying bacteria multiplied and remained in considerable number to the end of the ripening. The presence of large numbers of such enzyme-producing bacteria during the ripening

suggests they may have contributed to the process. It was especially significant to find that: 1. This cheese ripened in the center before it did on the outer edge, as would be expected if the bacterial enzymes aided in the ripening. 2. The final product was in flavor and texture not very different from the more typically ripened cheeses. This would seem to suggest that while the normal ripening is not due to the bacteria or enzymes in the body of the cheese but to the organisms on the surface, under some circumstances the former may materially contribute to the process, and while producing a somewhat abnormal ripening, will give in the end a similar result.

From the facts thus outlined we have reached the conclusion that the bacteria in the body of the cheese are in normally ripening cheeses concerned only in the souring of the curd as preparatory to the later changes. This leads, naturally, to the study of the organisms present in the outer layers. This rind contains a variety of molds and bacteria. The presence of certain molds in the rind of every Camembert cheese examined suggested from the first that they must be important agents in the ripening process. This has been demonstrated in the preceding section; but this rind also, under most circumstances contains many bacteria. Our study of these bacteria and their actions is not yet complete. We have as yet no good evidence that their action is necessary to the production of a first-class product. That they occasionally modify the final cheese is quite certain, and we are also convinced that they play an important part in the ripening of the type we have called the American Brie. Whether they have any influence on the production of the typical Camembert flavor can only be determined by subsequent experiments.*

It should be finally stated that the surface of the ripening cheeses very frequently becomes covered by an abundant growth of yeast, a phenomenon which the makers call "sweating."

* Since the above was in type we have received from France through the Dairy Division of the Bureau of Animal Industry a set of cheeses selected and forwarded by M. Georges Roger accompanied by a letter giving data as to age and condition of ripeness. Studies from the surface of these cheeses have shown the presence of the same Penicillium we are using, of Oidium lactis, and of the same species of bacteria which appear on our cheeses and contamination with the same other molds we have met. These bacteria on the older cheeses formed reddish-brown slime almost entirely covering the cheese. Systematic tests of these red slime producing bacteria are being made to ascertain what effect they may really have upon the ripening of the cheese. Cultures made from the interior of the cheese showed practically pure cultures of lactic organisms as in our own cheese. These results suggest that we have the same organisms as M. Roger, though under different names.

At present we have no grounds for believing that this has any influence upon the ripening unless it be to check in a slight degree the drying of the surface of the cheese.

CHEMISTRY.

The chemical composition of a normal Camembert cheese is quite well known and considerable work in this line has been done. This work, however, is not of much help in studying the changes that take place during the ripening process and makes it necessary to go over the same ground that has been covered in the work done on Cheddar cheese.

The great difference in the making and ripening of Cheddar and Camembert cheese soon made it apparent that an entirely different set of factors are at work and that the chemical side of the investigation opened a field which would require considerable time to complete.

We have undertaken to follow the chemical changes which render the insoluble curd of a newly made cheese into soluble forms found in a cheese ready for consumption; to isolate and study the enzyme or enzymes which cause these changes; to investigate the changes which concern the production of the peculiar flavor which is characteristic of Camembert cheese; and to show the relation which each of the constituents of a newly made cheese bears to the ripening process.

Up to the present time all our attention has been given to work upon the nitrogen constituents of the cheese. This was because of an early belief, confirmed later to some extent, that the fat plays a secondary part in the ripening and in the development of the flavor in Camembert cheese.

The market product was first studied to establish a standard. This was secured from the analysis of a number of imported cheeses. Our cheeses compared favorably with these, yet we hope to obtain improvement by a slight modification in our methods of making and in handling the cheeses in the ripening cellar (*i. e.* acidity, humidity, temperature, and washing the cheeses).

The first change is the precipitation of the casein of the milk by rennet. This precipitate or coagulum carries down with it most of the fat and some of the milk sugar. The sugar is changed in a few days by bacteria into lactic acid, rendering the

curd distinctly acid in reaction to litmus. The fat undergoes some slight changes, but the precipitated casein undergoes a very marked modification.

Practically no change takes place in the cheese, except the development of acid during the first twelve days. Then the curd begins to soften and is gradually changed from an insoluble lump into a soft, creamy mass, almost entirely soluble in water. This change starts at the outside and progresses inward towards the center until the whole mass has been acted upon.

This change in the curd is probably due to one or more enzymes produced by the molds growing on the cheese. These enzymes begin their activity at about the fruiting time of the molds (about the twelfth day). They have not been separated as yet, but the evidence at hand seems to indicate the presence of both tryptic and peptic-like enzymes.

Some idea of the changes that take place can be obtained from the following table:

TABLE 10.

Laboratory No.	Age. Days.	Total Nitrogen. Per Cent. Cheese.	Nitrogen as mono-lactate. Per Cent. Cheese.	Nitrogen as water, soluble. Per Cent. Cheese.	Nitrogen as amids. Per Cent. Cheese.	Nitrogen as ammonia. Per Cent. Cheese.
25 a,	1	2.73	0.40	0.32	0.23	0.00
25 b,	3	2.73	0.41	0.41	0.21	0.00
26 a,	5	2.81	0.39	0.45	0.21	0.00
25 c,	6	2.73	0.41	0.54	0.27	0.00
26 b,	7	2.81	0.39	0.52	0.27	0.00
27 a,	8	2.92	0.43	0.53	0.26	0.00
26 c,	10	2.81	0.67	0.73	0.38	0.00
27 b,	11	2.92	0.62	0.75	0.61	0.00
28 a,	12	2.90	0.63	0.69	0.53	0.00
27 c,	14	2.92	0.57	1.65	0.48	0.00
28 b,	18	2.90	0.27	1.76	0.48	0.01
29 a,	19	2.65	0.34	1.59	0.43	0.02
28 c,	20	2.90	0.17	1.85	0.42	0.06
29 b,*	21	2.65	0.13	1.79	0.48	0.06
14,	28	2.61	†	2.09	0.46	0.21

* This series of cheeses went bad with bacteria after this sample was taken. For comparison the analysis of another cheese, No 14, is given.

† Not determined.

GENERAL CONCLUSIONS.

Although the results of these three lines of work are still incomplete, some conclusions have thus been reached which bear directly upon the practical problems. These conclusions have been put to the test of constant use since the establishment of our ripening cellar, and have brought a much better understanding of the problems involved than was before available.

It has been conclusively shown that the making of Camembert cheese is not dependent upon unique conditions obtainable only in very restricted localities, but rather upon securing the proper cultures and conditions which are possible almost anywhere. Cheeses made at this station have been compared with the best imported goods obtainable in America and pronounced practically identical, not only by members of the force, but by importers and connoisseurs who have eaten this type abroad. These cheeses are in no way inferior in texture or flavor to the best market article. They have been ripened by inoculation with pure cultures and have been watched constantly and tested by the bacteriologists, the chemist, and the mycologist at every stage of their ripening. The element of chance is thus excluded from the result. The organic agents involved are known. The difficulties encountered in the attempts to establish this brand of cheese making in the past have, therefore, been due to insufficient knowledge of the molds and bacteria involved in the process, rather than to failure in obtaining any peculiar conditions or the proper milk.

Our practical work also proves that it will be possible to control the ripening to such an extent as to produce a more uniform product. It has been the practice of the makers in the past to provide suitable conditions and then, as one has put it, let "nature do the ripening." As a consequence of this "hit or miss" way of doing things, some cheeses are inoculated with the proper cultures from the first, some bear one organism and not the other necessary, while wrong species of bacteria and mold very commonly grow in or upon the cheeses, so that the final results are very uncertain. This accounts in a large measure for the variation in appearance, texture and flavor of such cheeses, and is apparently responsible for the differences between the imported and the American made types. It became evident very early that uniformity depends upon the controlling

of the growth of bacteria and molds from the time the cheese is made until the close of the ripening. This pointed to inoculation as the best means of reaching the desired result. Experience has justified this conclusion at every step. The use of lactic starters in butter making had already established a simple means of controlling the development of bacteria. The control of the molds was a more difficult problem, inasmuch as there are at least two different molds, and to obtain a desired result depends upon keeping the proper balance between these two organisms growing upon the same surface, but having different functions. We have learned that by varying the conditions and growth of the Penicillium we can, to a large extent, control the development of the other mold. Oidium will not grow profusely upon a cheese already covered with the white mold, and by developing a luxuriant growth of the latter we can hold the former largely in check. Cheeses in which the Oidium has not developed abundantly are mild in flavor or lacking entirely in the typical Camembert flavor. We have succeeded in producing cheeses perfectly ripened so far as texture is concerned, but flavorless; others with the flavor distinctly developed but mild, and others again with a strongly developed Camembert flavor. Our experiments thus far seem to show that by controlling the growth of these two molds we can control both ripening and flavor production, although as above suggested we have not yet absolutely excluded the possibility that bacteria may play some part in the process of flavor production.

The important practical problem then appears to be to devise methods of treatment that will enable the cheese maker to control the growth of micro-organisms, and primarily the lactic bacteria and two species of molds. The control of the first process of souring of the curd is very easy. It is only necessary to apply here the method now so widely used in cream ripening, the inoculation of the milk with lactic starters. These starters, if placed in fresh milk, ensure a proper souring with perfect uniformity.

The control of mold growth is a more difficult matter, because of the great likelihood that the cheeses in handling will become inoculated on the surface with other than the desired organisms. The solution of the problem, however, appears to be found in proper attention to three factors.

1. The inoculation of the cheese at the proper stage with a comparatively large quantity of the spores of the desired organisms. At just what stage the inoculation should be made and in what way we are not at present prepared to say. The question of direct inoculation of cheese with two molds as a means of controlling ripening is an entirely new one in the discussion of this cheese problem. The practice of the factories has been to allow the cheese to develop the proper mold after entering the ripening room. But there seems to be a good reason for a change in this particular. Milk as it reaches the factory already contains the germinating spores of many species of fungi. Some of these forms develop even more rapidly than the ones essential to our purpose. The proper mold has never been found by us in thousands of cultures of milk as it comes from the barn, while undesirable species are very common. If the Penicillium essential to cheese ripening is to take and maintain the ascendency in the ripening process, it is imperative that it should begin to grow as soon as the cheese is made. Although further experience is necessary to determine the best time and manner of the introduction of the molds, we are convinced that their early introduction gives advantages more than compensating for the additional labor involved.

2. The cleanliness of the ripening cellar. The cheeses remain in the ripening cellar from four to five weeks, where the conditions are kept ideal for mold growth. If the walls, shelves or floors are allowed to become covered with a growth of miscellaneous molds, their spores are sure to reach the cheeses and are then liable to produce trouble. The remedy for this is cleanliness in the ripening room. Special care should be taken to prevent the growth of undesirable molds.

3. The treatment of the cheese in the cellar. We have learned that variations in moisture and temperature of the ripening cellar, and different methods of handling the cheeses all greatly influence the growth of the molds and bacteria. A perfectly uniform method of handling is therefore necessary for perfect uniformity in results. Differences in little matters of

detail are found in the treatment of cheeses in different factories, and these become the basis of each maker's brand. Some wash their cheeses, others do not. Some turn them more often than others. Some send them to the market in a greener condition than others.

In this introductory paper only the general principles can be outlined, and we hope to follow this paper shortly with another giving in detail the actual methods of making and handling, which we have found most successful in producing the best product.

FUNGI IN CHEESE RIPENING.*

See B. A. I. Bul 82.

BY CHARLES THOM.

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CAMEMBERT AND ROQUEFORT. (85)

It has been shown in a previous bulletin that certain fungi are the active agents indispensable to the ripening of Camembert cheese. The general results and the data upon which they rest are there discussed. The more special mycological studies involving several lines of work remain to be brought out in greater detail. These fall naturally under two heads: (1) The physiological studies of the functions of particular species in the ripening processes of Camembert, Roquefort, and certain related types of cheese. (2) The classification and description of these and other forms occurring in dairy work. This paper will include the work that has been done under the first head only. The description of the dairy fungi occurring will be reserved for another paper.

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* The experiments in cheese making are conducted in coöperation with the Dairy Division of the Bureau of Animal Industry, United States Department of Agriculture.
L. A. CLINTON.

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CAMEMBERT. RESUMÉ OF PREVIOUS PAPERS.

The biological conditions and the physical changes encountered in the production of a Camembert cheese from market milk may be restated from our former bulletin as a basis for defining the special problems of the mycologist.

Milk as ordinarily received contains bacteria of many species and the germinating spores of numerous fungi from the stable and from the food of the cattle. When such milk is curdled for cheese making, representatives of all of these species are enclosed in the mass or coagulum. Freshly made cheese from this curd, then, may contain any species of mold or bacterium found in the locality, which is capable of living in milk or its products. The first step in the ripening of a Camembert cheese is the production of lactic acid. The lactic bacteria* very soon increase their rate of multiplication so enormously as to become entirely dominant. The acid produced by these forms soon reaches a per cent. sufficiently high to restrict the further growth of nearly every other species of bacteria, and even to eliminate the organisms themselves when present. In a time varying from a few hours to three or four days, according to the proportional numbers of these antagonistic species at the start, further bacterial growth seems to be entirely stopped. Bacterial development can not begin again until this acidity is reduced below the critical point for the species involved and even then, since the acid is neutralized on the outside first, for most species, it begins at the surface and works slowly inward. The uncertainties due to the presence of many species of bacteria in the milk are in this way avoided by the natural, simple and practically universally successful process of souring.

* Storrs Agricultural Experiment Station Bulletin No. 35, p. 25.

The further ripening of a Camembert cheese is attended by a gradual reduction of this acidity until the ripe cheese is usually alkaline to litmus. At the same time the mold action produces chemical changes in the mass of curd, which in from three to five weeks reduce the previously insoluble mass to a high percentage of solubility in water. In the latter stages of this ripening, compounds are formed which give the characteristic odors and flavors to this type of cheese. Associated with these chemical changes there is a progressive physical change from the firm curd to a soft buttery or even semi-liquid texture, characteristic of ripe cheese. The biological problems then were, in general, the determination of what organisms cause:

1. The changes in the acidity of the curd.

2. The changes in the casein with the associated changes in the physical character of the cheese.

3. The production of the flavors.

4. The recognition and control of deleterious species.

CULTURE MEDIA AND METHODS.

The common dairy fungi grow readily upon any of the standard culture media. Among the media used have been peptone agar, whey gelatine, sugar gelatine with or without the addition of litmus, milk agar, gelatine and agar made with Raulin's fluid, potato agar, potato plugs, and sterilized milk and curd. Special studies have involved other preparations. The fact that these fungi grow readily upon all of the common media has led to the selection of two preparations for constant use, and the careful study of all species found upon these. For this purpose the sugar gelatine described by Conn* for the qualitative bacteriological analysis of milk, and potato agar have been used.

The sugar-gelatine formula produces a type of carefully made and accurately titrated medium in which every effort is made to secure a uniform composition. Although absolute uniformity in chemical and physical properties is never obtained, the reactions of many species of fungi, when grown upon successive lots of gelatine made after this formula, have been so reliable as to commend its use for determining physiological characters.

* Bacteria in Milk and its Products, p. 268.

It seems clearly shown, therefore, that slight variations in composition of the medium do not produce great differences in the species studied in this paper. In the discussion of the relation of a mold to this gelatine it must be borne in mind that the same results might not follow the use of any other formula.

Potato agar was selected because of its use in many mycological laboratories. In the preparation of this medium, uniform composition can hardly be claimed. The following process has been used in this work. The potatoes are carefully washed, pared and sliced, then slowly heated for about two hours in approximately two volumes of water. At the close of the heating the water is allowed to boil. The whole is then filtered through cloth, and commonly also through cotton; water is added to make up the losses of evaporation and filtering. To this is added one per cent. of shredded agar. It is then heated in the autoclave to 120° C. or higher, for from twenty to thirty minutes, when it may at once be put into tubes for use, or if cloudy it may be very quickly filtered through absorbent cotton, after which it should be quite clear. The uncertainties in the composition of this medium result from the differences in the potato extract itself and from the fact that the difficulties in filtering this extract take out a varying amount which is replaced with water. Titration shows that this medium is nearly neutral (4–6 acid on Fuller's scale) in cases tested to phenolphthalein, consequently it is used without neutralizing. Culture and study of the same species upon successive lots of this medium show that these differences in composition have little if any effect upon the morphology of the species studied.

Petri dish cultures have been used continually because they admit of direct study under the microscope. Slanted test-tubes were found useful for stock cultures and for gross studies of physiological effects, but are of little value for comparative work. It is useless to attempt to get a correct idea of the normal gross structure of these molds from fluid mounts. The extremely delicate hyphae are so tangled in such preparation as to give but very little idea of their ordinary appearance, while the chains of conidia break up immediately when placed in any fluid. Such mounts are useful and necessary to get at details of cell structure and cell relations, but in comparative

studies of species of such a genus as Penicillium their value is only that of a useful accessory. The primary source of comparative data must be direct study of the growing colony undisturbed upon the culture medium, with the best lenses that admit of such use.

This method of study recognizes that morphology is the basis of fungus determination, but takes into consideration:

1. That morphology must not only include the minutest details of cell structure and cell relations such as are undisturbed in fluid mounts, but also the appearance and character of the colony.

2. That the morphology of the colony—*i. e.* the size of conidiophore and fructification, relation of these to substratum, appearances and relations of aerial and submerged mycelium—is different upon various substrata, but has been found to be characteristic for each particular substratum.

3. That a description of morphology to be of value must therefore, specify the formula of the medium used and the conditions.

Dilution cultures have been necessary usually to obtain the colonies pure, but the direct transfer of large numbers of spores upon a platinum needle to the surface of gelatine or agar plates which have been allowed to cool have been found to give equally reliable results and to have many advantages for the study of species once obtained in pure culture. This is often spoken of as inoculation of cold poured plates. Litmus solution may be used with either gelatine or agar and gives striking evidence of differences in, and in the rate of the physiological action of different species. Bacterial contamination has been usually restrained by the addition of from two to four drops of normal lactic acid to eight or ten cubic centimeters.

EFFECT OF A FUNGUS UPON A CULTURE MEDIUM.

In studying the relation of a fungus to a culture medium we find (1) that the fungus absorbs food from the surrounding medium; (2) that it may secrete or excrete substances into the medium which may transform its chemical composition and its appearance. The amount of food absorbed by the fungus

is small, and for our purposes may be practically ignored; but the changes induced by indirect action—secretions from the mycelium—are great and far reaching. To this latter group belong the changes in acidity, digestive effects and flavors produced by fungi.

LITERATURE OF CHEESE FUNGI.

A review of the literature at the outset showed that no work on the fungous flora of the various types of soft cheese had been published in English. Epstein at Prague studied the ripening of Camembert and Brie cheeses. He attributes the changes in the curd in French Brie to the action of Penicilliam album (?), but denies the participation of molds in the ripening of Camembert. Johan Olsen in Sweden has published a brief review of the fungi related to the ripening of Gammelost, barely mentioning work done upon Camembert. Marpmann in Leipzig has listed many fungi as found in studies of cheese. Constantin and Ray in France have described the appearance upon the cheese of the species of Penicillium involved in the ripening of the French Brie. Roger, also in France, has attributed a single phase of Camembert cheese ripening to the activity of *Penicillium candidum*,* for which he gives no description. Of these references, that of Epstein and that of Constantin and Ray describe the mold found upon the French Brie sufficiently clearly to aid in its recognition. A popular article in the Creamery Journal of October, 1904, gives in entirely untechnical language a very satisfactory description of the appearance upon cheese of the Penicillium concerned in the ripening of Camembert. The general insufficiency of the literature available made a first hand study of the types of cheese found in the American market the only source of material and definite information.

BIOLOGICAL ANALYSIS OF A CHEESE.

In the biological analysis of a market cheese it is carefully unwrapped to avoid contamination as far as possible. Series of dilution cultures on neutral and acid media are made at once from each part of its surface which shows any variation in appearance. In this way all the surface molds and bacteria

* The use of the specific name P. candidum is probably incorrect.

are secured in one set of plates. Afterward this surface is examined in detail, usually with a lens, the appearance of the different areas is noted and direct transfers from each area are made to cold agar or gelatine plates. The cheese is then cut with a sterile scalpel and cultures are made from various portions of the interior. Usually the transfers were made from the center and from the area just inside the rind. Any part showing special appearances is reserved for a separate series of cultures.

Most of the brands of Camembert cheese found in our market, also some sent by Roger, have been examined in this way. For comparison similar studies have been made from several specimens of Roquefort cheese bought in different markets, and from individual specimens of Gorgonzola and Stilton. Single studies for molds have been made from Limburger, Port du Salut, Brinse, and from several brands of prepared cheese found in the market. From these cultures all species of bacteria found have been isolated and handed over to the bacteriologists. Every variety of mold occurring upon these cheeses has been isolated and studied. It has been possible in this way to show that a comparatively small number of species characteristically occur upon soft cheese. Although this list may be greatly extended by including forms which are occasionally found, it is rather surprising to find a restricted group of species occurring with much regularity in studies of cheese from so widely different countries.

To study the origin and distribution of these molds several laboratories and cheese factories have been visited and cultures taken. Correspondents in distant states have kindly sent cultures of molds occurring in their work. Among those who have sent material are Dr. C. E. Marshall, Agricultural College, Mich.; Mr. E. G. Hastings, Madison, Wis.; Professor F. C. Harrison, Guelph, Ont.; Dr. H. A. Harding, Geneva, N. Y.; Professor P. H. Rolfs, Miami, Fla. Thus, in addition to a large number of cultures from the dairy laboratories of the Station at Storrs and at Middletown, we have accumulated a considerable number of species representing the characteristic molds occurring in dairy work from several sources, as well as many forms collected in the field, and from laboratories not associated with dairy investigation.

THE FLORA OF CAMEMBERT CHEESE.

Although a considerable variety of molds appeared in cultures from Camembert cheeses, a list of possibly twenty species would include those which were often found. Among these there are perhaps six species of Penicillium, two or three of Aspergillus, Oidium lactis, Cladosporium herbarum, one or two of Mucor, one or more of Fusarium, Monilia candida and two species perhaps related to it, with the incidental occurrence of Acrostalagmus cinnabarinus, a Cephalosporium, various species of Alternaria and Stysanus. Besides these, yeasts in large numbers and considerable variety are found in many cases.

THE CAMEMBERT PENICILLIUM AND THE OIDIUM LACTIS.

The comparison of the results of culture with comparative studies of the surfaces of different brands of cheese showed that one species of Penicillium was present upon every Camembert cheese examined. In partially ripened cheeses this mold often covered the larger part of the surface. We shall call this the Camembert Penicillium or the Camembert mold. This species develops a large and characteristic growth of aerial mycelium in addition to a densely felted mass of threads which penetrate the outer one or two millimeters of the surface of the cheese, and which largely constitute the rind. In all except a few very old cheeses, which were almost covered with red slime of bacterial origin, it was readily seen to be the dominant species upon the surface. Similarly, cultural data showed Oidium (Oospora) lactis to be abundant upon every brand of Camembert. This mold is practically indistinguishable upon the surface by its characters except under very favorable conditions, and at best its recognition, even with a hand lens, is not often certain. Mycelium of this fungus develops only in very moist substrata and is usually entirely submerged. Only part of its chains of conidia even rise above the surface. In old and very ripe cheese when the rind is covered with yeasts and bacteria it is often difficult, under the microscope, to find the spores of Oidium. In such cases, unless one is familiar with the peculiar smell associated with its action, he must depend entirely upon the culture for evidence of its presence.

No other species of mold has been found upon every cheese examined, although no market cheese has failed to show contamination with at least one or two of the other fungi listed above. In other words, comparative biological examination of imported Camembert cheeses established the fact that these two species of mold were present upon them all, however abundantly they might be contaminated with other forms. The examination of hundreds of cheeses in the city markets has shown the presence of the same two molds upon all the brands of Camembert offered for sale. Such analysis clearly established the presence of these molds upon the ripe cheese, but gave no information either as to whether they were necessary or what function, if any, they might have.

Experiments were therefore devised to test the relationship of these molds to the ripening processes outlined above. The constant occurrence of other molds also upon the cheese brings up the question, How and to what extent do they affect the ripening process? The experiments have been made to include as many species as possible therefore. Where detailed chemical analyses were necessary the work has necessarily been restricted to a few forms.

For this purpose in addition to the Camembert Penicillium and Oidium lactis, the Penicillium found in Roquefort cheese (der Edelpilz of German authors) has been usually used. For convenience it is called the Roquefort Penicillium or Roquefort mold. One of the Mucors probably Mucor (or Chlamydomucor) racemosus, is so commonly found that it has been often included. A pure white mold closely related to the Camembert Penicillium has given some interesting contrasts. When reference is made to any of the numerous undetermined green species of Penicillium, they will be indicated by the letter or number under which they appear in the record book of cultures, and under which the origin and subsequent cultural history of all species studied has been kept.

These studies involve two classes of data, (1) those experiments requiring quantitative analyses which have been conducted in coöperation with Mr. A. W. Bosworth, chemist to this investigation. The results of such series of analyses will appear in his report; (2) experiments which show the physiological characters of the fungi by physical changes in the

appearance, texture or color of the medium used, or by the production of flavors. The results may be anticipated here by noting that these two classes of data did not prove mutually interdependent, but that chemical analysis may show in general the chemical conditions found in a ripe cheese without the necessary texture and flavor and conversely the practically necessary texture and flavor may be obtained in a cheese differing considerably in its chemical condition from the standard market article. In our practical experiments we sought first for proper appearance, texture and flavor of the cheeses, then without disturbing these, endeavored so to control chemical changes of the casein as to satisfy the standard of chemical composition established from the study of market cheeses.

1. RELATION OF MOLDS TO ACIDITY.

The development of lactic acid has been shown to be of primary importance in the control of deleterious bacteria. In our previous paper it has also been seen that after doing its work this acidity gradually disappears in the ripening process. The disappearance of the acid has been attributed by Roger (Rev. Hebd. 7 pp. 334) and by Epstein (Archiv. f. Hyg. XLV. pp. 373) and by Mazé to the activity of molds and interpreted as preparing the way for the action of peptonizing bacteria. This view of the relation of molds to cheese ripening has been widely quoted as their only function in the process.

The acid exerts practically no selective action upon any of the molds studied. Stoll has recently shown that species of Penicillium grow readily in media containing much higher percentage of acid than ever occurs in cheese work. The use of acid in fungous cultures to restrain bacteria is practically universal. But the action of the different species of mold upon the acid is very different. This is strikingly shown by the introduction of a solution of litmus into the culture media used. Litmus gelatine or litmus agar may be a deep blue if used at 15 acid on Fuller's scale as is usual for bacterial studies, or a clear bright red if two to four drops of normal lactic or other acid are added to 10 cubic centimeters of medium. No mold cultivated in this work has failed to show some definite relation to acidity indicated by litmus reaction. Some fungi as soon as they develop visible colonies begin to change red (acid)

media to blue (alkaline) and maintain this character consistently. Many others when grown in blue gelatine (designating by *blue*, gelatine 15 points acid to phenolphthalein—10 points alkaline to litmus on Fuller's scale) begin by changing the blue to red. This change may vary from the faintest tinge of red in only that part of the medium directly in contact with the threads of the young colony to deep red over large areas. Oidium lactis and Roquefort Penicillium produce at times a very slight pink, which barely traces the outer limits of the young colonies before the blue reaction begins to appear. At other times the red if appearing at all has been so evanescent as to be overlooked. It has been suggested that this slight appearance of acidity might be due to the excretion of carbon dioxide in respiration, which although continuous, is afterward masked by many times larger changes in other substances.

The Camembert Penicillium, and several of the very common green species of Penicillium, when grown upon blue gelatine, at first turn all the substratum in contact with the growing colonies to a bright red. Some species produce areas of red beyond the limits of the mycelium. These effects are most clearly seen by examining the colony from the under side. Later a spot of blue appears in the center of the colony below and gradually extends outward, until commonly the entire mass of culture medium has become blue. This often involves a change of reaction in agar or gelatine two to three centimetres beyond the colony. It is thus clear that there must be either the secretion or the excretion by the mycelium into the medium of a substance capable of changing this reaction, or the absorption from the medium of some substance, thus changing its reaction. The exact nature of this change has not been determined. Increase in the percentage of acidity or of alkalinity retards the change of reaction. In certain experiments phenolphthalein was introduced into red litmus media and several species of Penicillium and Oidium lactis were grown upon it. With the Camembert Penicillium the entire mass of agar became blue in a few days, remained so for nearly three weeks, then the characteristic pink color for the alkaline reaction of phenolphthalein appeared on the under side of the colony. This was tested by opening the colony with a platinum needle and introducing a very small drop of normal acid, when the pink

area was changed first to blue and then to red. As the acid diffused outward from the center the wave of blue travelled outward, being replaced constantly by red until all trace of the phenolphthalein reaction was gone. The other species used did not give this reaction. There are forms including some species of Penicillium, Aspergillus niger, Monilia fructigena, and others, which produce the acid reaction in litmus media without any change to blue. Several species of Penicillium rapidly produce the purplish color which is characteristic of the turning point of litmus at which their further development occurs, apparently these bring acid or alkaline media to that point without further change. It would appear then that the relations of these molds to acidity as indicated by the litmus reaction is reasonably uniform. To determine whether the litmus reaction would be reliable upon a medium closely allied to cheese, test tubes of separated milk were prepared, blue litmus added, and the tubes sterilized. Eleven species of Penicillium were inoculated into these tubes and observations were made every day. Of these, four species including the Camembert Penicillium produced a layer of red milk for a few millimeters below the colonies which later was changed back to blue. The other species either intensified the blue or produced no change.

The suggestion has been made that neutralization of acid is due to the production of ammonia. A series of cultures were made in coöperation with Mr. A. W. Bosworth to test the production of ammonia compounds by mold action. The species used were the Roquefort Penicillium, the Camembert Penicillium, Penicillium sp (Record No. 310), Oidium lactis, Oidium sp (Record B), and Aspergillus niger. These were grown upon potato agar to which litmus and lactic acid were added. The Aspergillus culture remained bright red, all the others became deep blue. Upon analysis the Aspergillus niger was found to have produced the largest amount of ammonia. Study of the figures showed that the ammonia alone was not sufficient to neutralize the acid used in any case. It is clear then that the lactic acid must have been neutralized by some other basic products of digestion rather than neutralized by ammonia. If the acid were absorbed and dissociated after absorption the area of blue would be restricted to the neighborhood of the hyphae or the diffusion of the acid for considerable distances would

produce purple tones instead of sharply marked areas of red and blue. The data seem to indicate that chemical decomposition or neutralization of acid must be the action of some product excreted by the fungus, probably an enzyme.

It has thus been shown by many experiments that the Camembert Penicillium and Oidium lactis are two of many species capable of reducing the acidity of the media upon which they grow. Many other species of the same genus produce this effect more quickly than the Camembert Penicillium. Some act at about the same rate as this one. The reduction of the acidity of the cheese may clearly be attributed to these molds, but the study of the relations of many other molds to acids indicates that any of a large number of species might be equally or more useful for the accomplishment of this step in cheese ripening. If, therefore, these particular molds are essential to Camembert cheese ripening their special function must be sought in other steps of the process.

2. THE DIGESTION OF CASEIN.

The changes in firm sour curd which result in the production of the soft buttery or semi-liquid texture of the Camembert cheese present some very complex problems. These may be grouped as (1) the purely chemical questions which involve qualitative and quantitative analyses of the material at every stage; (2) the biological and physical questions which deal with the agents and conditions which produce these results and with the gross appearances of the final products whose descriptions do not depend upon detailed chemical analysis.

1. The chemist (Bul. 35, p. 29) describes the general course of these processes and the nature and extent of changes as a digestion in which the insoluble or but slightly soluble compounds of casein found in sour curd are rendered almost completely soluble in water. The details of the process and the data will appear in the report of the chemist later.

2. To determine what relations the molds might have to the chemical changes involved a great many cultures on different media. In some experiments the number of species used was large and the results acquired in that way a comparative value, but in the more complicated trials the work was limited to those mentioned above.

It is practically impossible to produce a normal cheese in such a way as to avoid contamination with bacteria or molds. It is difficult, therefore, to study the relations of organisms to the steps of cheese ripening directly upon cheese. Even were this possible the complexity of the changes encountered would make the interpretation of the phenomena difficult. The activities of these molds have, therefore, been studied in pure culture upon a series of media which would give information as to steps of the process. While these cultural studies were being made many cheeses were made and inoculated with the Camembert and Roquefort Penicillia. The measure of success obtained from cheese inoculated with the Camembert Penicillium gave good practical ground for its continued study. These detail studies may be best discussed separately.

LIQUEFACTION OF GELATINE.

The liquefaction of gelatine media has been much used as an index of digestive activity. All species obtained have been grown upon neutral and acid sugar-gelatine and the effects noted carefully.

The difference in action between the molds important in this investigation are striking. The Mucor produces a slow but rather complete liquefaction; Oidium lactis will gradually soften the gelatine so that the center of the colony is liquefied; a pigment producing Penicillium (recorded simply as "O") will liquefy all the gelatine in contact with it so quickly that it comes to be a floating colony in a watery pool twice its own diameter in a week. Several other species of Penicillium have the same effect. The Roquefort Penicillium softens gelatine somewhat, but never produces a watery liquefaction. The Camembert Penicillium often produces a slight liquefaction under the center of the colony, but never extends that liquid area to half the total size of the colony. This seems to indicate that the Penicillium "O" and its allies would produce a rapid digestion, that the Mucor would be somewhat slower, that the Camembert mold might have some digestive effect, and the Roquefort mold very little, if any, value. The test of the ability to liquefy the gelatine used gives therefore only indefinite or negative results as to any advantageous relation of these particular species to cheese ripening.

Comparative study of numerous cultures of many species of fungi upon gelatine gives, however, some very interesting suggestions. In many species which liquefy litmus gelatine rapidly, the area of liquefaction is surrounded by a blue (Alkaline) band. For example, in one experiment with Penicillium "392," at its most active period of growth a colony fifteen millimeters in diameter was surrounded by a liquefied area four to eight millimeters wide. This area was in turn surrounded by a band of intense blue shading gradually in a width of perhaps ten millimeters into unchanged red litmus-gelatine. The medium which had been liquified was almost colorless. Several suggestions may be drawn from many such observations. The change in acidity of the medium as has been noted above may be affected at a distance of two to three centimeters from the colony. This change of litmus reaction advances faster than the area of liquefaction of the gelatine. The breadth of the area of liquefaction shows that the action of the fungus is not a digestion by contact, but the secretion into the medium, of diffusible digestive agents, *i. e.*, enzymes. In most of these species liquefaction occurs only in areas having alkaline reaction. No general relation between acidity and digestion is established. The substantial uniformity of the results of repeated cultures of the same species of fungi upon gelatine made after the formula used, established its usefulness as a test of the ability of an organism to perform this particular digestion. It will be shown later that the ability to liquefy this variety of gelatine is not to be regarded as a general test of the ability of a species to produce active proteolytic enzymes.

RAULIN'S FLUID.

To test the ability of these species to grow in a medium entirely lacking in proteid, Raulin's fluid was used as given by Smith and Swingle (B. P. I. Bulletin 55) but modified by leaving out the potassium silicate and zinc sulphate. Sterilized flasks of this solution were inoculated with Mucor, Oidium lactis, Camembert Penicillium and Roquefort Penicillium. All four grew. The Oidium lactis and Mucor did not appear to develop entirely normally. Both species of Penicillium grew richly and fruited normally. The culture of the Camembert mold, after growing several weeks, was examined chemically

and a proteolytic enzyme was demonstrated to be present, in digestive experiments conducted by Mr. Bosworth. In this way it was shown that this fungus could not only construct proteid from inorganic compounds of nitrogen but would produce proteolytic enzymes in such a solution. Enzyme studies were not made for the other species used in this experiment.

CASEIN.

For a medium at the opposite extreme, the chemists prepared pure casein. This was weighed into two gram lots moistened, sterilized in the autoclave and inoculated with five species of mold. All grew and fruited luxuriantly. This experiment showed only that the species used were able to break down casein and to grow normally upon the products of this digestion without the addition of other nutrients.

STERILE MILK AND CURD.

Sterilized milk and sterilzed curd offer a substratum related to cheese. Sterilized milk in quantities varying from forty cubic centimeters to one hundred and fifty cubic centimeters in test-tubes and Erlenmeyer flasks has often been used. Nearly all species of Penicillium grow luxuriantly forming a felted mass of mycelium often two to four millimeters in thickness upon the surface of the milk. With the absorption of the milk in such cultures of the Camembert and Roquefort species the mass of mycelium buckles and bends, tubercles of mycelium arise on the under side of the mass and grow downward keeping the mold in connection with the fluid. In this way a culture may continue to grow for several months until it forms tough, irregular masses of felted hyphae, filling the test-tube for an inch or more downward from the original surface of the milk. The milk below the colony soon becomes transparent giving reactions for digestion, with a residue of curd at the bottom, which in the course of time may be almost completely dissolved. With the Oidium lactis on the contrary the colonies largely sink below the surface so that the milk may be quite well filled with mycelium upon which chains of spores are only produced in quantity at or just below the surface. Similar experiments with 100 grams of sterilized curd in flasks, inoculated with the Camembert and Roquefort molds have shown

that either species is able to change the chemical composition until the derivatives of casein are almost completely water soluble. Such cultures were plated to show their freedom from contamination by bacteria before analysis. The resulting products give the standard reactions for digestion. These experiments show that either of these molds is capable of producing digestive changes comparable in their completeness, rapidity and general nature to those shown by analysis to have occurred in the ripening of Camembert cheeses.

DOES THE MYCELIUM PENETRATE THE CHEESE?

It must be noted carefully that this action of the Camembert mold goes on without the complete penetration of the substratum by the mycelium of the mold. That this is true is readily seen in milk cultures where the limits of the development of the mycelium are sharp and clear. The same fact has been demonstrated for cheese by hundreds of sections and careful cultural studies many times repeated. The mycelium forms a dense mat upon the surface of the fluid or the mass of curd, or the newly made cheese. It follows the irregularities of the surface and is not found to enter well-packed curd to any extent. It is very difficult to prove that hyphae of this mold actually appear in curd of uniform texture below one or two millimeters. When found deeper in, careful search usually shows a cracking of the surface so that the mycelium may follow the opening already made. In no case of many hundreds of cheeses studied and experiments performed has the mold been found to fruit in cavities not opening broadly upon the surface. This is in marked contrast to the habit of the Penicillium instrumental in the ripening of Roquefort cheese, which penetrates the channels of the substratum and fruits in every cavity large enough to accommodate a conidiophore. The Roquefort mold will make every cavity in a cracker or piece of bread green with spores, while the Camembert mold will fruit upon the surface of the bread or cracker with only vegetative mycelium inside the bread.

Definite experiments to prove that this digestive power on the part of the Penicillium is due to the secretion of one or more enzymes, have given characteristic reactions for digestion many times. Without discussing these chemical reactions

here, it has been shown that the action of the fungus is carried on at distances from the mycelium which preclude direct action. The enzyme, must therefore be secreted and diffuse outward from the mycelium into the substratum. This explains why the Camembert cheese begins to ripen just under the surface and why this action progresses inward from all sides until the cheese is entirely ripe. Before this process is complete the center is simply sour curd. A good illustration of this action is seen in cheeses which are ripened without turning. In such cases the development of mold and enzyme on the lower surface is prevented and as a consequence ripening is delayed on that surface.

CAMEMBERT PENICILLIUM UPON CHEESE.

Many cheeses have been made and inoculated with this mold alone in conjunction with pure cultures of lactic starter. Little difficulty is found in this, since if an abundance of spores are put upon the cheese when made, this mold seems capable of taking and maintaining the lead of all others. A cheese made in this way and ripened for from three to four weeks will finally be rendered creamy, or under some conditions, waxy throughout; in color, white within; in flavor, almost neutral; having no particular character good or bad, and hence to a lover of Camembert cheese, tasteless and insipid. The important features of this ripening process are then, the completeness of its action and the entire absence of any objectionable character in its flavor. Biological analysis has shown that the center of such a ripened cheese may be practically a pure culture of lactic organisms. The texture is, therefore, obtainable by the use of the Penicillium alone.

COMPARATIVE STUDIES OF FUNGOUS DIGESTION.

Comparative tests of digestive action have been made for a number of molds. The Roquefort Penicillium has been used in parallel cultures with the Camembert Penicillium in many determinations. It has shown equal or greater ability to digest milk and curd. A typical example of several series consisted of cultivation of eleven species of Penicillium upon sterilized milk in large test tubes. Observation of results after seven

days showed digestion by seven of these species. Five of them appeared to digest milk at least twice as rapidly as that species, in the first week.

In another series, milk agar was made by dissolving one to two per cent. of the agar in water at 130° C. and pouring together equal quantities of the hot agar and hot sterilized milk. If poured into petri dishes at once this medium was smooth and clear, but if acidified or sterilized after mixing, flakes of precipitate appeared. The flaky precipitate in the acidified cultures was found very useful as an indication of digestion. In cultures upon the surface of such plates where digestive action was strong, the flakes would entirely disappear. Twenty-three species of mold were tested upon milk agar in this way. Of these, eight produced a distinctly stronger digestion than the Camembert Penicillium; five produced digestion approximately equalling that species, and ten produced less digestion. These cultures were mostly made in duplicate and both results in all but two cases agreed fully. Oidium lactis produced comparatively little effect upon this medium.

TABLE 11.—*Reactions of Certain Species.*

	Litmus.	Liquid Gelatin.	Digestion of Curd.	Digestion of Milk.	Growth at 5 to 10 degrees C.
Camembert,	red, then blue	partial	medium	medium	slow fruiting
Roquefort, -	blue	softening	rapid	rapid	characteristic
Oidium, - -	blue	incomplete	slow	slow	characteristic
Mucor 12, -	blue	incomplete	slow	—	poor
Mucor 191,	blue	incomplete	slow	—	—
'O' - - -	blue	rapid	rapid	rapid	—
300, - - -	blue	partial	medium to rapid	rapid	retarded
132, - - -	red, then slowly blue	slight	medium	—	—
310, - - -	red, then blue	slight	slow to medium	slight	slow
68, - - -	red, then blue	partial	slow	medium	slow fruiting
Monilia candida No. 198,	blue	rapid	rapid	rapid	—
P. brevicaule,	blue	rapid	rapid	rapid	—
392, - - -	blue	rapid	slight	rather slow	—
240, - - -	blue	rapid	rapid	—	—
Aspergillus niger, -	red	rapid	—	slow	—
135, - - -	blue	rapid	—	rapid	—
136, - - -	red to purple blue	partial softening	medium	—	characteristic

Two species of Penicillium, "68" and "310," found closely associated upon cheese with the Camembert Penicillium, produced little digestion. The Roquefort Penicillium and several other molds often found upon Camembert cheese appeared to act much more rapidly than the Camembert mold itself.

All of these series of cultures under different conditions, many times have shown the same results and prove that the *ability to digest curd* is *common to many species of fungi.* The species we have been led to call the Camembert Penicillium possesses this character in common with numerous other molds, many of which act more rapidly than this one.

After the ability of several molds to digest curd is established, the relation of any particular mold to cheese ripening must be determined by the character of the products of that digestion and the flavors associated with it. No pure culture upon a medium previously sterilized by heat has given a taste resembling that of Camembert cheese. Cheese made and kept in an atmosphere of chloroform, which prevented mold and bacterial development, refused to ripen. Numerous cheeses made and not inoculated with molds have uniformly failed to develop the texture and flavor of Camembert cheese; although such cheeses have usually become covered with molds of various species. The type of cheese made and sold in this country as Isigny and Brie, and sometimes labeled Camembert, which always shows Oidium lactis associated with bacteria, differs entirely in appearance, texture, odor and flavor from Camembert; yet Oidium lactis is capable of neutralizing the acid of the cheese much more rapidly than the Camembert Penicillium.* The necessity for the presence of another agent in this ripening is clearly established.

More than two thousand cheeses have been made and ripened at this Station with the Camembert mold under varying conditions. Hundreds of these cheeses have shown repeatedly that cheese so made will assume in ripening the texture of the best imported article. The Camembert Penicillium, therefore, is seen to be able to neutralize the acid of the freshly made cheese and to produce the texture desired, but not the flavor. It remains to determine whether other molds may not be equally

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* Nevertheless the center of such a cheese remains acid for a longer time than is required to ripen a Camembert cheese while the texture of Camembert is not produced.

useful in this process. For comparison, cheeses have been made and inoculated with the Roquefort Penicillium, with undetermined species of Penicillium appearing on the record as "O," "300," "310," "68," "132." Of these species one, "310," when cultivated upon every medium used except the cheese duplicated the reactions of the Camembert mold completely. Its morphology is scarcely distinguishable. It differs only in that it remains pure white during its entire cycle of development, while the Camembert species turns gray-green in age. The close relationship apparent, together with a promising test, led to its use upon over 100 cheeses. The changes in curd resulting from its action were widely different. These cheeses were drier, waxy, with a mealy, crumbling layer just under the rind. The physical character of the results and the flavor produced were so different that the cheeses were entirely worthless. This mold was originally isolated from a market Camembert cheese where it was found mixed with others.

The presence of the Roquefort Penicillium may be seen by the spots of green it produces and may be detected by a sharp, bitter, perhaps astringent taste. The texture of the cheese produced is different and the flavor, when it is present in any large amount, is so strong as to be very objectionable to many. When present in small amounts upon a cheese it gives a certain sharpness or piquancy to it, such as has been often found in certain brands of imported cheese and is sought for by some buyers.

The species marked "O" and "300" secrete a bright yellow pigment into the cheese which colors every area with which it comes into contact. A cheese was inoculated with "300" and examined when eight weeks old. It had produced no trace of the texture of Camembert. The center of the cheese remained practically sour curd, while the portion for perhaps one-fourth of an inch under the colony was decomposed.

The species marked "68" has been obtained from cheese from widely different sources. In cultures upon milk and milk agar it produced little action upon the casein. A cheese inoculated with it remained largely sour curd for two months. The species marked "132" is a very common green form, appearing in dairy and other cultures. It has given no satisfactory results when grown upon cheese. In this way, related species found in cheese work have been tested in their effects upon

cheese and shown not to produce changes comparable in physical character to that demanded in a Camembert cheese, and constantly obtained by the use of the Camembert Penicillium. There seems to be no further question but that this species of Penicillium, among all the molds so far studied, is the only agent capable of producing the characteristic texture of the best type of Camembert cheese with no objectionable flavors or colors.

FLAVORS.

All attempts to produce the flavor of Camembert cheese in pure cultures of milk and curd with particular organisms have failed. Here again we have had to depend upon the use of cheeses so that direct, positive proofs have not been possible. The value of the indirect or circumstantial evidence offered must depend upon the completeness with which all factors have been considered. It has been previously shown that a cheese may be ripened to the texture of the best Camembert by the action of lactic bacteria and the Camembert Penicillium (P. candidium or album?) but that it will lack flavor. A series of difficulties are met here. The typical flavor does not begin to appear until ripening is well along. This would indicate that the flavor producing agent or agents must act upon already partially ripened cheese to produce the particular *end-products* which give this flavor. But coincident with this the acidity of the curd has become so far reduced that bacterial development may now occur on the surface at least, and as a matter of observation few cheeses begin to show flavor until cultures from their surface show swarms of bacteria of various species. It has not been practically possible to change these conditions sufficiently to make cheeses bearing only pure cultures upon the surface. The problem becomes then one of comparative study, and the elimination of the unnecessary factors one by one rather than the direct production of the flavor sought in a single conclusive experiment.

Some organism or organisms must be sought for to produce the flavor. The appearance of the flavor of the imported article in certain experimental cheeses at this stage of the investigation led to their immediate study. This showed that Oidium lactis was abundant upon these cheeses and emphasized

the fact that it had always appeared in cultures from market cheeses. Oidium had been excluded from many experiments in cheese making because it had been found to be associated with odors that seemed undesirable, as well as because of the conclusion of Epstein from his researches, that the presence of Oidium is uniformly deleterious. The inoculation of a half-ripened cheese lacking flavor entirely, with spores of Oidium produced the flavor distinctly in a single week, but since bacterial action seemed always associated with this, further evidence was necessary. Roger and Epstein have attributed the ripening of Camembert to the action of certain bacteria without distinguishing that the production of the texture of the cheese is accomplished by a different agent from the production of flavor. In their descriptions, ripened Camembert is always referred to as slightly reddish in color, and the appearance of this color is regarded as an indication of the progress of ripening. In cheeses selected and forwarded by M. Roger this red color was very prominent and the red layer was found to consist of myriads of bacteria of a few species. Cultures from these cheeses showed that Oidium lactis was also present in abundance. Numerous tests have been made with the bacteria found associated with the various brands of Camembert cheese hitherto without producing the flavor in any case independently of the molds. The comparative study of many cheeses from the market and from our own cellars seem to show that cheeses may have the typical Camembert flavor without the development of any specific surface growth of bacteria. The character of the bacterial growth upon the surface appears therefore to be incidental or accidental, though its presence may be necessary as maintained by Mazé in a recent paper, to exclude air.

Cheeses of good flavor have both been produced here and purchased in the market which indicate that particular surface appearances are not essential to the typical flavor. Similarly the introduction into new cheeses of species of bacteria found in cultures from the interior of good cheeses has produced either no effect whatever or disagreeable flavors. Thus far, therefore, no species of bacterium has been found capable of producing the Camembert flavor. Although the flavor question is manifestly still unsettled, we may offer the following summary of the data at hand upon relation of molds to flavor in Camembert cheese:

1. Oidium lactis has been found in every brand of Camembert cheese studied.

2. It has never been found upon a ripened Camembert cheese which lacked the flavor.

3. The flavor has never been found in a cheese without the Oidium.

4. Every other species with which the flavor seemed obtainable has been eliminated from one or more experiments without loss of flavor.

5. Bacteria or other molds do in many cases modify the flavor of Camembert cheese but do not seem to be able to produce it independently of the mold. There thus arise characteristic secondary flavors which are associated with the output of certain factories and which command special markets. These varieties are usually more highly flavored than what we have regarded as typical.

The essential relation of the Camembert Penicillium and Oidium lactis to the production of Camembert cheese is, therefore, well established. Several mycological questions remain. What are the optimum conditions of temperature and moisture for the use of these molds in cheese ripening? What are the most practicable means of cultivating material for inoculation? How can the proper inoculation with these molds be most effectually secured? What other fungi occur as contaminating species and how can they be controlled?

TEMPERATURE.

Since the higher temperatures of the ripening cellar lead more rapidly to the development of bacteria it is necessary to determine the lowest temperature which will permit mold growth and also enzyme action. The different species respond quite differently to temperature. In one experiment eight species were inoculated into slanted tubes of gelatine and put in a refrigerator where the temperature varied from 5° to 10° C. Of these the Camembert Penicillium and two nearly related species Nos. 68 and 310 grew, but fruited very slowly, showing an inhibiting effect. The Roquefort Penicillium grew and fruited normally as also did Oidium lactis. The species of Mucor used developed very slowly and fruited only slightly.

Two of the very common green species of Penicillium grew richly. Oidium lactis grows abundantly in the Brie and Isigny cellars visited. In these the temperature was 50° to 55° F. (11° to 12° C.). Numerous experiments in the ripening cellar show that the Camembert Penicillium does not grow at its best in a room cooler than 60° F. (15° C.) and that to obtain rapid development the room should be slightly warmer. Until this mold is well established, therefore, it is distinctly an advantage to grow it at a temperature of 65° to 70° F. Repeated experiments have shown that lowering the temperature to 52° to 55° F. checks the rate of ripening very materially. A difference of less than ten degrees between two rooms will often make as much as two weeks difference in the ripening period of cheeses from the same lot in the two rooms. A temperature as low as 54° to 55° F. as given in an article in the *Creamery Journal* referred to above appears to prolong the ripening period without contributing any compensating advantages. A half-ripened cheese was cut, the progress of the softening of the curd was noted, and the cheese put in a refrigerator where it was held for four weeks at 48° F. It was then found to be completely ripened and perhaps a little old in one place, but the changes noted at the end of this period would have been produced within a single week at 60° F. The cold storage possibilities suggested by this experiment will be further studied.

Some experiments were made to show the resistance of spores to heat. The spores of the Camembert and Roquefort Penicillia were inoculated into gelatine and placed in an incubator. Heating for an hour and fifteen minutes at 56° C. killed all spores of the Camembert species. Only a few spores of this mold grew after one hour at the same temperature, while some spores of the Roquefort Penicillium grew after two and a half hours.

HUMIDITY.

The use of very moist cellars and caves in the ripening of this class of cheeses is practically universal. The richest development of mold is seen in rooms where the atmosphere is saturated or nearly so. This appears to be exceptionally true for species like Camembert Penicillium which is purely a milk fungus, and in which there is a large development of thin-walled

aerial mycelium. So dependent is the Camembert mold upon abundance of moisture that it has been found difficult to secure a rich growth upon the surface of a cheese which has been drained for two or three days before inoculation. Contrary to directions commonly given for ripening these cheeses, which call for a particular degree of humidity, cheeses have been ripened successfully in our cellars at the saturation point as well as at the various degrees of humidity below that. A good illustration of a mold which has adapted itself to changes of moisture is found in a mold numbered 198.* Upon a fresh cheese in a moist room, this organism forms a circular ring-like colony of floccose hyphae standing often eight millimeters high upon the surface of the cheese. In a drier situation, or when the cheese is nearly ripe and the rind becomes harder and dried, the same mold produces conidiophores which barely rise above the substratum so that the surface of the cheese is covered by a white powdery layer which is practically pure spores. The mucors are so sensitive to moisture that they scarcely develop upon the cheese, except sometimes during the first few days when the surfaces are very wet. They appear to be unable to withstand the rate of surface evaporation in the ripening cellars.

INOCULATING MATERIAL.

The problem of propagation of the Camembert Penicillium for inoculation purposes presents some difficulties. This species bears spores only upon the surface of the culture medium used, in contrast to the Roquefort species which develops spores in every air space when grown upon bread as well as on the surface. To produce spores in quantity, therefore, material must be capable of sterilization and must present the largest possible amount of free surface in proportion to the space occupied. For the preparation of such material quart fruit jars have been used. Various styles of crackers have been tried. Most of these were not successful. The most suitable appears to be the hard, dry "water cracker." The jar is filled with crackers, and dry sterilized at 140° to 160° C. for an hour or more, better twice on successive days. The spores may be added directly

* Comparison with exsiccatae in Harvard University Herbarium identified this with specimens labeled Monilia candida. But this is not M. candida as understood by Hansen.

or first inoculated into about 100 cubic centimeters of sterile water (acidified with 1.5 per cent. of lactic acid usually) and this poured into the jar and shaken until all the crackers are wet. Various types of "milk cracker" soften to a pasty mass in this moistening process. The best water crackers are not very satisfactory, because the mycelium tends to transform bread or cracker into a soft gummy mass. The crackers become overgrown and matted together until they present much less actual surface than might be expected. The substitutes tried have been excelsior, hay and sheets of cardboard wet with milk or whey. Although some of these have advantages, they were on the whole less satisfactory than the "water crackers."

So far, therefore, no material has been found so easily prepared and so satisfactory as the "Schimmelbrot" of the Roquefort cheese makers, on account of the very different habit of our mold.

From the point of view of the use of pure cultures the Oidium lactis is even more troublesome. This mold produces a large proportion and in some strains all of its spores as chains below the surface of the substratum. For pure culture work petri dish cultures have been the only satisfactory means used. Its enormously rapid development, however, makes possible the propagation of a culture from day to day from the draining boards upon which the cheese is made. These become heavily coated with a slimy mass of mycelium and spores upon standing over night. Direct transfers from them have been used with apparently no serious trouble from contamination. In fact so capable is the Oidium of self-propagation in dairy work that Epstein declares it to be present in all dairy work. Although Roger in his published statement does not mention it at all, it was found abundant upon the cheese forwarded by him to this Station. We have succeeded by careful work in making many cheeses entirely free from Oidium but with the ordinary treatment of dairy utensils it appears constantly in factory practice. It is practically possible to rely to a considerable extent upon the ability of the Oidium to propagate itself as has hitherto been done in the factories.

INOCULATION WITH PENICILLIUM.

With the Penicillium however numerous experiments indicate that there is much advantage in early and effective inoculation from the cultures of known purity. Whether such inoculation must be always made from specially grown laboratory cultures is questionable. In factory practice, making room and ripening cellar are usually adjacent rooms. If precautions are taken always to have on hand some cheeses bearing pure cultures (and the cheese maker must know his mold so well that there will be no question about it) one or two such cheeses will furnish enough inoculation material for much newly made product. This would be indicated by the rough calculation that from the abundance of the chains of fruit and the size of the spores (.005 millimeters in diameter) probably there are about enough spores produced to cover evenly the surface upon which they grow, perhaps 25,000,000 to the square inch. Very successful inoculation in seventy-five pounds of milk has commonly been secured by tapping a petri dish culture over the vat or by breaking a piece of cracker about an inch square or less and stirring it into the milk.

The most economical and successful method of inoculation so far devised has been the use of sprinkling jar or can. For this purpose holes one millimeter or less in diameter in the jar lid are demanded. A small amount of water is put into the jar, a piece of cracker or cheese covered with mold is broken into the water, the top is then screwed on and the jar thoroughly shaken. The water is then sprinkled upon the newly made cheese at the time of first turning, so that both sides of each cheese receive a few drops of water. Excellent results have been obtained in this way with the smallest amount of inoculating material and the least requirement of labor and skill. Such a jar should be emptied and washed immediately after using. The mixture is made fresh each time. Milk may be used instead of water as was first suggested and tried by Dr. Conn, but the water has been found the most easily managed. The practical method for factory use will probably vary with the conditions and skill of the maker.

VITALITY OF SPORES.

Studies have been made upon the vitality of the spores of the species used. This varies greatly in different species. In some of the most common forms spores have been reputed to remain viable for several years. Recent studies by Wehmer showed that five species of Penicillium used in his experiment were entirely dead in laboratory cultures at the end of two and one-half years. Cultures of the Camembert Penicillium grown upon potato in test tubes plugged with cotton have refused entirely to germinate at the age of one year. Other cultures have seemed entirely dead inside of six months. In fact the spores of this mold are very thin-walled and lose in percentage of viability very rapidly when stored. Under such conditions they lose turgidity and become crenulated or indented. Spores of Monilia candida and several others have grown after more than a year in laboratory cultures, but their germination was much retarded. Oidium lactis seems to be very easily killed by drying as would be expected from a species with such thin-walled spores. The Roquefort Penicillium under some conditions is more resistant but loses vitality quite rapidly. It is certain therefore that material for inoculation should be fresh and vigorous to give the best results. Under ordinary circumstances it would not be desirable to attempt to use material more than a few weeks old.

CONTAMINATIONS.

The number of molds found upon market Camembert cheese shows the need of care in guarding against contamination of cultures. Extraneous molds may come (1) from the milk (2) or from the utensils used, (3) from the clothes and hands of the workmen. Although the milk is the primary source of most infections, practical experiments have shown that if the proper molds are put upon the cheese at the time of making the troubles arising in this way may be minimized. In fact, sufficient contamination from this source directly to ruin a cheese is very uncommon.

The very habit in some countries of washing or rinsing cheese making utensils in whey will account readily for the universal presence of Oidium lactis and perhaps for many of the bacterial infections that result in loss. But the source of the most

trouble in a cheese cellar is found to be the cheese maker himself. The cheeses are commonly exposed upon curing boards, turned and examined in the hands. In this way spores from molds or bacteria occurring accidentally as single colonies upon single cheeses are distributed by thousands to hundreds of cheeses. The product of a factory may almost be identified in the markets by the contaminations upon the surface of its cheeses. Certain brands of the cheese always bear Monilia candida, and commonly one or two other Monilias. A species of Fusarium is distinctive or another brand with Acrostalagmus cinnabarinus occasionally present. After numerous experiences with all sorts of contamination this trouble has been practically eliminated from our experimental work by putting the fresh cheeses as soon as they are drained, salted and comparatively dry upon the surface, into boxes which are slightly larger than the cheeses, leaving air space and room for mold to develop normally. In this way fingering is done away with, the cheese is turned by turning the box, and examined by removing the lid without touching the surface, so that a colony of mold appearing upon one cheese is no longer distributed through the cellar.

It is, therefore, possible to produce cheeses practically free from molds other than those inoculated upon their surface. Although such boxing is practically undesirable on account of expense upon a large scale, it remains certain that it may be very useful in eliminating troubles which do occur without so large a loss as would come from discarding all infected cheeses, many of which would ripen very satisfactorily but for the danger of spreading obnoxious fungi over great number of cheeses.

ROQUEFORT CHEESE.

The well known Roquefort cheese is another highly flavored cheese in which mold has long been known to play a part. In manufacture, this cheese approaches the hard type, but the ripened cheese bears a closer relation to the soft cheeses. Many very complete descriptions give the details of its making and curing. These need not be repeated here. Roquefort is by description a goats' or sheep's milk cheese, made in France principally, though cheese of nearly the same quality is said to be made in other parts of Europe from mixed cows' and sheep's milk, or from cows' milk alone.

The great popularity of Roquefort cheese makes information as to the biology of its ripening processes very desirable. To this end numerous specimens of Roquefort have been purchased and analyzed. The results of this work have been very much simpler than the studies of Camembert. The ordinary Roquefort cheese, before it is sent to the market, is carefully cleaned and covered with tin foil. Its surface would, therefore, tell very little. When cut it is seen to be traversed by channels or holes made by the Prickelmachine and by cracks. Every air space is lined with green Penicillium so that the cut surface is said to be marbled with green. The texture of the cheese is reasonably uniform with every indication that ripening is simultaneous throughout the cheese or at least approximately so. Its texture is rather crumbling than waxy, with a tendency to dissolve readily in the mouth. The taste is characteristic, a sharp flavor, in which a rather high salt content is noticeable. Its odor is strong, cheesy rather than offensive in any way, except as pronounced putrefactive odors are sometimes developed in the rind. Cultures from the surface often show various species of fungi. There is no regularity about the surface, however, while uniformity of texture and appearance is universal on the inside. Cultures from the interior show a remarkable uniformity. In many cheeses examined a pure culture of a single species of Penicillium has been found. The extremely rare appearance of any other mold in the cultures has been remarkable. Similarly the bacterial content is usually limited to typical lactic forms. Sufficient analyses have been made to establish clearly that a first-class Roquefort cheese should contain only lactic bacteria and the Roquefort Penicillium. This Penicillium is often referred to by writers as P. glancum and regarded as *the common green species*, but as it has very characteristic morphological and physiological characters it seems best to designate it as the Roquefort Penicillium, even though it quite often occurs upon other substrata.

The cultures which have been conducted in connection with the study of Camembert cheese have shown that the Roquefort Penicillium is capable of digesting curd very completely. Here as in Camembert cheese, chemical analyses have shown that the derivatives of casein become almost completely water soluble.

Further, pure culture experiments upon sterile curd have shown that this mold in the earlier stages of ripening produces bitter flavors during the first few weeks, but that its continued action changes these to typical flavors of the Roquefort cheese. Here we have a definite positive result. It is thus shown that the Roquefort Penicillium, acting with the lactic bacteria, is capable of ripening Roquefort cheese, without the introduction of other enzyme producing or flavor producing organisms. The investigations of the chemical nature of these changes have barely been touched upon at this time. In a recent experiment a cheese of the Roquefort type was made of cows' milk, inoculated with the Roquefort Penicillium, and kept in a room at a temperature of about 60° F. At the end of five weeks this cheese was found to have acquired both the texture and the flavor of genuine Roquefort. There seems to be no doubt but that it will be possible to develop methods of making and ripening that will produce the Roquefort type of cheese successfully in the United States. Details of making and handling will then be offered.

OTHER CHEESES RELATED TO ROQUEFORT.

Single studies have been made from the Italian Gorgonzola, English Stilton and Hungarian Brinse (Brindze or Brimse). Gorgonzola and Stilton are made from cows' milk. Brinse is described as made from sheep's milk, mixed sometimes with goats' milk. These three varieties of cheese are found marbled with green Penicillia in pure cultures, which are unquestionably one or more strains of the Roquefort Penicillium. In the Gorgonzola and Stilton cheeses examined, lactic species were the only bacteria found. Comparison of the flavors in these cheeses shows that the differences lie rather in the qualities of the materials used in making, and in the handling of the cheese, than in the qualities attributable to ripening organisms.

It is peculiarly interesting to find the same species of mold in the interior of ripened cheese in four countries so widely separated, where no efforts at the use of pure cultures are known to be made. Experiments show that in every locality so far studied there are many green species of Penicillium. It is evident then that the food material or the conditions or both presented by these types of cheese must exert a selective influ-

ence upon the molds, which results in the dominance of the one species so universally found. This species has been introduced into experimental cheeses at this Station.

AMERICAN BRIE AND ISIGNY.

Cheeses of the type referred to in our previous bulletin as the American Brie have been studied for comparison. This was a collective term suggested to cover cheese sold under various labels as Brie, Isigny, Wiener, Miniature and others, designated commonly by the retailer simply as Brie. The name Brie seems to be applied in the French dairy literature to a cheese which differs from the Camembert in the process of making, but ripened by the same fungi and approximately in the same way as Camembert. The domestic product so far as examined is quite different, with the exception of the out-put of one factory which is conducted by imported cheese makers. The cheese met in the eastern markets under these names shows no trace of the Camembert Penicillium. Numerous brands have been examined in the market and many hundreds of cheeses have been seen in the cellars of two of the largest cheese companies. Oidium lactis is universally present upon these cheeses, but its presence goes practically unnoticed by the makers since it produces neither color nor aerial mycelium. All noticeable molds are washed or scraped from the surface of the cheese. The washing produces exactly the best conditions for the growth of bacteria and Oidium. This treatment results in a cheese without a very definite fungous rind, with a strong flavor and smell.

Cultures from this type of cheese indicate that there is an associative action between the Oidium lactis and various species of bacteria. Several species of Penicillium occur as contaminations in these cellars, and sometimes are found upon the cheeses in the market. Every effort is made to eliminate mold action other than that of Oidium lactis, which usually passes unrecognized. Cheeses of this type usually bear rich growths of yeasts, giving a characteristic greasy feeling to the surface. Exactly what parts these various organisms play in the production of Brie is as yet undetermined.

Single studies have shown that Oidium lactis is the dominant mold upon the surface of some brands of Limburger, brick and

Port du Salut. There is then good reason to believe that this fungus is associated with nearly every type of highly flavored ripened soft cheese met in the American market.

THE MOLDS REFERRED TO IN THIS PAPER.

The Camembert and Roquefort molds belong to the hyphomycete genus Penicillium, which has been characterized by one author, "hyphae broadly effused, creeping; conidiophore branched at the apex in an irregularly verticillate manner, producing brush or broom-like forms; conidia in chains, hyaline or bright colored, spherical or elliptical."

This genus of fungi contains a large number of very poorly described forms which are everywhere abundant as the "green" or "blue" mold of the household, the dairy and the granary. They form patches upon and just under the surface of the materials upon which they grow. The patches are composed of delicate threads of mold which are matted together, forming more or less cottony surfaces, never rising more than a small fraction of an inch above the substratum. At first these areas are always white, but in most species the ripening of a crop of spores is indicated by the change to a color which is usually some shade of green, though this may later give place to a brown. In a few species other colors appear. These spores (conidia) or propagating bodies are minute, thin-walled cells averaging possibly one five-thousandth of an inch in diameter, and so light that they float freely in the air. A breath upon the surface of such a colony carries away thousands of them, when if held in a proper position, they may commonly be seen to rise in a cloud. If the colony be held to the nose and inhaled they give the sensation commonly called the "smell of mold." They are then exceedingly light; they are produced in immense numbers; they are capable of growing in almost every conceivable situation, upon anything which is not definitely and strongly poisonous. Some of these spores are short-lived, others cling tenaciously to their power to germinate. Of the species probably a dozen common ones may be expected in any locality, perhaps more. Our studies have shown that they affect very differently the substances upon which they grow. It is then clearly necessary that we know the forms we are to use by thorough study of their characters and habits,

and just as important that we know how to get rid and stay rid (if it be possible) of those we do not want. The discussion of the whole group will be reserved for another paper. Here we may describe in simple terms the two cheese fungi we find important, but it may as well be acknowledged at the outset that with the possible exception of the Camembert species, safe recognition of species without technical knowledge and cultural study is out of the question.

THE CAMEMBERT MOLD.

The spores of the Camembert mold grow rather slowly in comparison with the other molds of the group. They first swell to nearly double size, then produce fine threads or hyphae at from one to three points on their surface. Upon a cheese or in laboratory culture the subsequent growth of these threads forms a colony large enough to be visible with the naked eye, in ordinary room temperature, in about two days. Usually in four or five days the colony will have become loosely white cottony, about one-half inch or less in diameter, and perhaps standing one-twentieth of an inch above the surrounding surface. At or about this stage the center of this colony begins to turn a shade of greenish grey, which is characteristic of this species, though one or two other forms produce colors closely resembling it except to one very familiar with the shades of color in question. This is due to the presence of ripe spores. Upon the cheese in the cellar this color often does not appear in less than a week or even ten days. Microscopic examination shows that the submerged threads of mycelium of such a colony do not go deeper into the solid media than one-sixteenth of an inch, and that the superficial portion of the mycelium spreads as fast or nearly so as the part beneath the surface of the substratum. This fungus grows and fruits for about two weeks, in some cases this may be prolonged to three weeks, and at the end of that period no further growth is to be expected from the primary colonies. Nor if the medium is undisturbed is there a secondary growth from the germination of the spores produced by the first colony. In case the rind of the cheese is broken so that a fresh surface is presented, the spores will develop new colonies upon such areas. A colony then produces a single crop of spores and dies, under ordinary

circumstances, and in undisturbed cultures there is usually no second growth from the spores or from the old mycelium, although the contrary has been claimed for this fungus by a recent writer (Mazé, 10). A cheese inoculated with this mold will become covered with pure white, cottony mycelium in about a week. The color will then begin to show the grey-green shade characteristic of the species, which spreads until at the end of the second week the entire surface, if left undisturbed, will be colored.

Persistent search has failed to find a single colony in America whose presence can be attributed to anything but Camembert cheese, imported from Europe. The mold may then be regarded as a typical dairy form which is not well adapted to cosmopolitan conditions, and to the struggle for existence on all sorts of media. In fact in the course of laboratory practice involving thousands of cultures, even in the laboratories of this Station, this mold rarely appears as a contamination, although it has been cultivated in quantity and used in the inoculation of large numbers of cheese in the same building with the bacteriological laboratory. Moreover, the spores are easily killed by heat, and retain their vitality for only a few weeks in ordinary cultures allowed to dry in the air at room temperature.

The following technical characterization may be offered, based upon studies made upon the sugar gelatine and potato agar described in this paper, after the plan outlined in my recent paper in the Journal of Mycology.

*Penicillium Camemberti (nomen novum).**—Colonies effused, white (sometimes yellowish white) slowly changing to grey-green (glaucous); surface of colony floccose, of loosely felted hyphae about 5 μ in diameter, reverse of colony yellowish white; conidiophores 300-800 μ in length, 3-4 μ in diameter, septate, cells thin-walled often collapsing in age, arising as branches of aerial hyphae; fructification sometimes 175 μ in length but usually much less, consisting commonly of one main branch and one lateral sparingly branched to produce rather

* In offering a new specific name for this mold the author is aware that the name *P. album Epstein* is accepted for this mold by Mazé and others; also that Lindau has substituted for P. album Epstein, P. Epsteini Lindau on examination of the literature alone. The previous use of the name P. album by Preuss for a fungus now unknown invalidates that name as used by Epstein. Careful study of Epstein's article and of the diagnosis of P. Epsteini, drawn by Lindau from Epstein's article, shows that this description offered would be incorrect if applied to this fungus. This opinion has been discussed with and concurred in by Dr. C. Wehmer.

few basidia which bear long loosely divergent chains of conidia. Basidia 8-11×2.4-3 μ. Conidia at first cylindrical then elliptical and finally globose when ripe, smooth bluish-green by transmitted light, thin-walled and commonly guttulate, 4.5-5.5 μ in diameter, swelling in germination to 8-10 μ. Germ-tubes one to several. Cells of mycelium about 5 by 20-40 μ. Liquefies sugar gelatine only under the center of the colony. Changes blue litmus to red strongly at first, then after four to six days begins to turn the red back to blue at the center and continues outward concentrically until all has become blue. Growing and fruiting period about two weeks. Fruits only upon *exposed surfaces* of the substrata—never produces spores in cavities not very broadly open. Habitat, Camembert and other soft cheeses.

THE ROQUEFORT MOLD.

The spores of the Roquefort mold grow very rapidly, often producing new mycelium and ripe spores within thirty-six hours. The colonies are white at the very first but begin to become green at the center within two days in a rapidly growing colony. Such a colony may become a half inch in diameter in the first two days. The mycelium is mostly submerged but very close to the surface and grows rapidly outward from the starting point in a radial manner, which is rendered prominent by certain of the threads lying just under the surface for the most part, but making loops into the air by rising just above the substratum for a little way then reëntering the medium. This gives a greyish, almost cobwebby (arachnoid) appearance to the margin of the young colony. The rate of growth is not uniform in the circumference of such a colony, which makes the border of a colony uneven instead of regularly circular as most species appear. The superficial portion of the Roquefort mold is almost entirely composed of the fruiting hyphae or conidiophores, the vast majority of which arise as branches of submerged hyphae and consequently stand separately as short unbranched threads of approximately equal length, which give the surface a velvety appearance. They are usually two or three tenths of a millimeter or less in length, say one seventy-fifth of an inch. Such a colony spreads indefinitely in the substratum so that the center will be composed of ripe fruit while the margin is still actively growing. In

laboratory culture, however, the development is so rapid that the entire surface is covered within the first few days, then growth ceases. The mycelium here, as in the Camembert mold, produces but a single crop of spores, then dies. These spores are a bright green at first, but in a short time become a dirty brown color in dry culture. The spores of this fungus are much more resistant than those of the Camembert mold both to heat and to natural exposures. They will retain their viability for months in old cultures, under the ordinary conditions of exposure in the laboratory. Upon a cheese this mold produces a bright green area which extends rapidly. Its action can be detected in a few days by the bitter taste of the curd near to the mycelium. A similar taste is, however, produced at least in some measure by other green forms so that it is not diagnostic except as between this and the Camembert species. A colony upon the surface of a cheese becomes brown in two or three weeks, but colonies growing in the cavities which are so characteristic of the center of this type of cheese retain their bright green color for long periods.

This mold is not limited to dairy products, but is widely distributed. It has been sent to the laboratory from the most distant correspondents. It has been found in silage, in laboratory cultures from many substances. It has been found to be the green mold of Stilton, Gorgonzola and Brinse, as well as in certain types of prepared cheese purchased in the market. Once in a laboratory it stays and seems to get into everything. In other words this is one of the cosmopolitan and omnivorous species of the genus. One character seems to differentiate this mold from most of the others—that is, its power of growing into and fruiting normally within narrow cavities, such as appear in cheese. It appears that this character exerts a sort of automatic (perhaps we may call it a truly "natural") selection which eliminates all other species from the ripening processes of Roquefort and related types of cheese.

A technical characterization, based upon petri dish cultures in gelatin and agar, is offered:

*Penicillium roqueforti (nomen novum).**—Colonies quickly turning green, becoming a dirty brown in age, velvety strict, indeterminately spreading by large main radiating, branching hyphae giving a somewhat uneven or indefinite margin, which gets a white, fibrous, almost spider-web appearance from its alternation of submerged parts of hyphae with short prostrate aerial loops; reverse of colony yellowish white. Conidiophores arising separately and in acropetal succession from the growing parts of submerged hyphae (comparatively few from aerial parts, but some), 200-300 μ septate. Fructification 90-120 μ or at times 160 μ by 30-60 μ at broadest place, usually appearing double by the divergence of the lowest branch, branchlets (basidiophores) irregularly verticillate bearing crowded verticils of appressed basidia, 9-11 by 2.5 μ, with long divergent chains of conidia. Conidia bluish-green, cylindrical to globose, smooth, rather firm walled, 4-5 μ in diameter, germinating by a straight tube. Colonies do not liquefy sugar gelatine though they soften it somewhat. Fungus changes litmus from red to blue very rapidly and strongly almost from the beginning of growth. Fruiting period short, but one crop of spores upon the mycelium. Cosmopolitan and omnivorous, or nearly so. Characteristic of Roquefort and related types of cheese. Fig. 2.

OIDIUM LACTIS.

The mold variously known as Oidium or Oospora lactis is another cosmopolitan organism. This fungus differs widely from the species previously described. Inoculated into any suitable medium it grows with enormous rapidity. A single spore (or oidium) may give rise to several centimeters of mycelium and hundreds of spores in twenty-four hours. It prefers very moist situations, since almost the entire mycelium is developed below the surface of the substratum. It is therefore passed unnoticed many times or produces changes which are attributed by the observer to bacteria. Description therefore must depend upon microscopic characters. The study of the border of the young colony shows numerous vegetative hyphae radiating outward. Each of these is found to divide dichotomously (fig. 3, a, b) so that the border is a crowded series of forking branches. In the older parts of the mycelium a branch

* The mold of Roquefort cheese is referred to in the literature only as P. glaucum. Careful study shows that this species has been confused with numerous others under the name P. glaucum. The unique position of this mold and its very distinct characters make it very desirable to have the name proposed above, Penicillium roqueforti.

may be produced at each end of every cell, or several at each end, and these branch indefinitely. The fruiting branches are mostly produced as outgrowths from the distal ends of the cells. These extend upward into the air or remain entirely submerged in many cases. From the ends of these outgrowths one to several rows of oblong or cylindrical cells begin to be pinched off. If extending above the surface this gives rise to chains of delicate shimmering cells which appear as a powdery covering upon the surface, which can be seen with a good lens to be arranged into chains. In some strains of Oidium all of these chains (and some of the chains in all strains) of spores remain submerged and germinate at once, so that they give rise to unintelligible mats of hyphae. Oidium produces a very slight acid reaction to litmus at first, then a strong and continued alkaline reaction. It liquefies sugar gelatine under the colonies, but does not extend the area of liquefaction beyond the edge of the colony. Oidium always and everywhere tested has produced a strong and very characteristic odor. Once familiar with this odor the worker may recognize it anywhere. Its spores or oidia are hyaline, smooth, cylindrical, 3.5-5 by 6-30, varying with the conditions and the substratum and perhaps at times exceeding these limits. These swell variously and germinate in many ways so that no germination characters are definite. Upon some media this mold may be induced to produce a large growth of aerial mycelium, but the limits here defined will include the variations to be found upon the usual culture media.

Oidium lactis is described as universally present on milk and its products. Epstein even suggests that experiments upon milk and cheese can not be freed from its presence without sterilizing. The same or almost indistinguishable forms are found upon decaying vegetables and fruits, which may give reason for the statement that the odor produced by Oidium is that of rotten cabbage. There seems to be good reason for saying that all these forms are but varieties or strains of the same species. Comparison of several of them shows that under uniform conditions the morphology of all these forms is very nearly the same. This is also largely true of their physiological effects. This mold has been much studied and numerous papers discuss its nature and physiological effects as well as its

relationship. It will be sufficient to describe here the fungus and to give figures to assist in its recognition. Its relations to the problems of cheese ripening have already been indicated.

SUMMARY OF THE RELATIONS OF FUNGI TO CHEESE RIPENING AS SHOWN IN THIS PAPER.

1. *Camembert Cheese.*—The acidity of the curd resulting from the action of lactic organisms reduces where it does not entirely eliminate the growth of objectionable bacteria.

2. Many species of dairy fungi exert in the course of their development the power of changing this reaction to alkaline. The Camembert Penicillium and Oidium lactis possess this power but not in greater degree than many other species.

3. Many species of fungi produce proteolytic changes in curd to a greater or less extent.

4. The chemical changes in the ripening of curd by fungi are due in the cases studied to the production of enzymes.

5. The texture, appearance and flavor of curd acted upon by such fungi are different for different species.

6. The Camembert Penicillium (P. Camemberti) is the only species so far studied with which the particular appearance and texture sought in the ripened Camembert can be produced from curd soured by lactic bacteria, without producing any objectionable flavor.

7. Oidium lactis is always found upon Camembert cheese and so closely associated with the presence of the flavor as to suggest its agency in flavor production though only circumstantial proof of such a function has been possible thus far. The participation of bacteria in flavor production is not excluded by these results.

8. Other species of fungi have been shown to produce variations in this flavor such as have been often found in certain market cheeses. In this way it is possible to look for the cause of differences in flavor in contamination of the cultures upon the cheeses. This points toward the use of pure cultures for inoculation with the addition of special organisms if certain variations from what we have regarded as typical flavor are found to be of value in the market, rather than dependence upon accidental occurrence of the desired species in the factory.

9. *Roquefort Cheese.*—In the ripening of Roquefort cheese the only organisms found necessary are lactic bacteria and the Roquefort species of Penicillium.

10. The Roquefort Penicillium has been shown to possess the power to reduce the acidity, to change the chemical nature of the curd, and to produce the typical flavor.

11. *Other Varieties of Cheese.*—The Roquefort species of Penicillium is found to be present in the imported Stilton, Gorgonzola and Brinse, as well as Roquefort cheese.

12. Oidium lactis alone of the forms studied has been found upon the various brands of Limburger, Brie (American type), Isigny and related cheeses found in the market. Other species incidentally occur but not uniformly; and such occurrence is avoided as far as possible by the makers.

Fig. 1.—Camembert Penicillium (P. camemberti):

a, conidiophore showing a common type of branching and the production of basidia and conidia, highly magnified.

b, a common form showing much less branching.

c, *d*, *f*, diagrams of large fructifications (x 80).

g, *j*, *i*, germinating conidia.

Fig. 2.—Roquefort Penicillium (P. roqueforti):

a, part of conidiophore and base of fructification highly magnified showing the production of basidia on the sides as well as at the apex of the basidiophore.

b, *c*, other types of branching.

d, young conidiophore just branching.

e, *f*, basidia and the formation of conidia, highly magnified.

g, *h*, *j*, diagrams of types of fructification as seen under low power (x 30).

k, *l*, *m*, *n*, germination of conidia and new conidia produced directly on the first hyphae.

Fig. 3.—Oidium Lactis:

a, *b*, dichotomous branching of growing hyphae.

c, *d*, *g*, simple chains of oidia breaking through substratum at dotted line xy, dotted portions submerged.

e, *f*, chains of *oidia* from a branching outgrowth of a submerged cell.

h, branching chain of oidia.

k, *l*, *m*, *n*, *o*, *p*, *s*, types of germination of oidia under varying conditions.

t, diagram of a portion of a colony showing habit or oidium lactis as seen in culture media.

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EXPERIMENTS ON THE DIGESTIBILITY OF FISH AND POULTRY.

BY R. D. MILNER.

The present article is a report of digestion experiments with poultry and fish which form part of the nutrition investigations carried on by the Station during the year 1904 in coöperation with the United States Department of Agriculture.

The object of these experiments was to obtain information regarding the actual nutritive value of poultry and fish. It has been explained in previous reports of this Station that for the proper estimation of the nutritive value of any food material, it is not sufficient to consider merely its percentage composition, that is, the amount of the different nutritive ingredients it contains. It is necessary to consider also its digestibility, or the amount of each ingredient that will be digested and absorbed, and so made of use to the body for the purposes of nutrition—the building of tissue, and the yielding of energy. Thus, two foods might be very much alike in chemical composition and yet, because of differences in digestibility, differ widely in actual nutritive value. This is known to be the case with graham and white flours. If these two grades of flour are milled from the same lot of wheat, their composition is found to be much the same, there being a little more protein in the graham than in the white flour. Bread made from the white flour, however, is much more completely digested than that from the graham flour. As a result the body actually obtains more nourishment from a given quantity of white flour than from the same quantity of graham flour.

Considerable information is now available concerning the digestibility of mixed diets in general, and of several different classes of food materials. As suggested just above, study has already been made of the digestibility and relative nutritive value of different grades of wheat flour. Experiments with

various cereal breakfast foods, with macaroni, with vegetables, legumes and with fruit and nuts may also be cited. Studies have also been made of the digestibility of milk, and of various meats, especially beef. The data at hand, however, are by no means complete, and in view of the importance of definite knowledge, much attention is now being given to this phase of the subject.

As regards the digestibility of poultry and fish but little is known. Analyses of these foods are extensive, and their chemical composition is well understood. The first at all elaborate series of investigations of food materials undertaken in this country were studies made by Atwater under the auspices of the U. S. Fish Commission, in 1878-81, on the chemistry of fish. The report of this Station for 1902 contained a large number of analyses of poultry. No attempt is here made, however, to summarize previous investigations. The object is merely to make a contribution to the general knowledge of the subject, which, so far as the digestibility of these foods is concerned is very meagre.

DETAILS OF THE EXPERIMENTS.

The work here reported comprises four series of experiments, two with fish and two with poultry. Each series consisted of four experiments, so that in all sixteen experiments were included. It was the purpose in the investigation, not only to ascertain the extent to which fish and poultry are digested, but also to compare, as far as possible, the digestibility of relatively fat and lean species. In the experiments with fish, salmon was used as a type of relatively fat fish, and cod as a type of lean fish. In the experiments with poultry, duck and chicken were similarly selected.

In the first series of experiments a simple ration was made up consisting of salmon, bread, milk, butter and sugar. This was consumed by each of the subjects for three days. The remaining series of experiments followed immediately, on essentially the same diet, save that chicken, cod and duck were substituted in turn for the salmon. All the food consumed and feces excreted during each experiment were carefully weighed and samples analyzed. The urine of the final day of each experiment was also collected, weighed, and its heat of

combustion determined. From the data thus obtained, the availability of the diet as a whole and of the fish or poultry alone was calculated as explained more fully beyond. The details of the separate experiments follow.

Subjects.—The subjects of the sixteen experiments were four men ranging from 19 to 38 years of age and from 60 to 75 kilograms in weight. All were engaged in light work in connection with the nutrition investigations. Each one took some physical exercise each day, the total daily amount of muscular activity being probably on the average about equivalent to that of a man at light muscular work. No attempt was made, however, to secure uniformity. The men simply pursued their ordinary course of life except as regards diet.

All the subjects were in good physical condition, with apparently normal digestion. Two of them, E. O. and R. D. M., had previously been subjects of digestion experiments, and the other two, from their experience in the laboratory, fully understood the nature and requirements of such experiments.

Duration.—In digestion experiments, as long periods as practicable are desirable, since thereby any error, as in the separation of the feces pertaining to the digestion period, would be mimimized. In these experiments the period was in each case three full days.

Diet.—In these experiments the diet consisted of the food under investigation, together with bread, sugar, milk, butter, and in some experiments duck-fat and rock-candy. No restriction was placed upon the amount of any food material to be eaten, each subject choosing what seemed to him to be sufficient to satisfy his needs. Some of the subjects endeavored to secure uniformity from meal to meal of at least a portion of the diet.

In order to compute the availability of the fish and poultry alone, as hereafter explained, the diet was purposely made as simple as possible consistent with palatability. Theoretically, an ideal diet for such experiments would consist of only the material studied; but such a diet, as pointed out in a previous report,* would not be practicable, and it is believed that results obtained by the methods here reported indicate more closely

* Storrs Expt. Sta. Rpt. 1904, p. 183.

the digestibility of these materials in the ordinary mixed diet, than would experiments in which the diet was limited to a single material.

Description of food materials.—In these experiments, well known brands of canned salmon and canned chicken were purchased at a local grocery. No preparation was necessary, other than the removal of a small amount of bone and other refuse from the chicken, and the materials were then eaten as purchased.

As a type of lean fish, fresh cod was selected. Several fresh cod steaks were purchased each day, cut into small pieces and prepared by frying. The pan was slightly greased with butter, and the fish thoroughly mixed with a knife during the cooking.

The duck used as a type of fat poultry was purchased uncooked, and prepared by roasting. The fat which cooked out in the process was carefully saved, and constituted the "duck-fat" hereafter referred to.

The bread was ordinary white bread purchased of a local baker, and was left at the laboratory each day. Immediately after purchase, it was stored in large glass jars in a cool place.

The milk used was from a mixture of the total product of several cows of a local herd. Milk from the same cows was included each day, as previous experience had indicated little variation in composition of such milk from day to day.

The butter was purchased at a local grocery, a fresh supply being obtained for each series of experiments.

The sugar was granulated cane sugar and was obtained at a local grocery. The rock-candy was a portion of a supply kept on hand for combustion work with bomb calorimeter.

Sampling of food.—As previously stated, the chicken and salmon were purchased in cans. At the beginning of the series of experiments, each subject was given one of these cans. At the first meal, each subject opened his can, transferred the contents to a large weighed bowl, and secured as thorough mixing as possible by stirring with a large spoon. Portions as nearly equal as could be easily estimated were then taken from each bowl for a sample for analysis. This procedure was

followed at the opening of each new can, and the composite sample thus obtained, after thorough mixing, was analyzed as representing the composition of the material.

Samples of the cod were taken from each portion fried, care being taken to secure a representative sample in each case. The mixture of the samples thus obtained was then analyzed.

The sample of duck was obtained by removing the meat from the cooked birds and carefully shredding it into as small pieces as possible. After thorough mixing, a portion was then removed for analysis.

The milk and bread were obtained fresh each morning, and aliquot portions of each were taken. The samples for all the days of an experiment were then mixed together and formed a composite sample for analysis. In the case of the milk, a few drops of formalin were added to the composite sample as a preservative.

Since the butter was purchased in amounts sufficient for an entire series of experiments, a sample was taken at only the beginning of each series. A single sample of the duck-fat was likewise sufficient.

No analyses were made of the sugar or rock-candy, as these materials are known to be of uniform composition.

Separation of feces.—In these experiments, separation of the feces pertaining to the experimental period was effected by means of lamp-black in gelatin capsules, taken with the first meal of each experiment and the first meal following the completion of the series, according to the method explained in detail in a former report.* In most cases the separations were quite satisfactory, though in some cases the line of demarcation in the separation at the end of an experiment was not so sharply defined as is desirable.

The feces pertaining to each experiment were collected, dried, weighed and ground for analysis.

Collection of urine.—The urine was collected for twenty-four hours of each experiment, beginning at 7 A. M. of the third day and ending at 7 A. M. of the day following. In the absence of any means of separating the urine pertaining to the experimental period and the lack of definite knowledge concerning

* Storrs Expt. Sta. Rpt. 1904.

the nitrogen lag, *i.e.*, the time elapsing between the ingestion of nitrogen in the food and its elimination in the urine, it was considered that this period could be taken as fairly representing the daily protein katabolism on the experimental diet.

The weight and heat of combustion of the urine were determined, and used in the computations of available energy, as explained beyond.

Analyses of food, feces and urine.—The analyses of the food materials and feces were made according to the methods adopted by the Association of Official Agricultural Chemists.* In the duck-fat sample, only the water content was determined. The ash content of the butter samples was assumed to be 2.50 per cent. in each case. Fat, in both the duck-fat and butter samples, was estimated by difference. Protein was taken throughout as equal to N × 6.25.†

The heats of combustion were made in the usual way by means of the bomb calorimeter.‡ The composition and heats of combustion of food materials and feces and the heats of combustion of the urine are given in Table 12.

From the table it will be noted that the most striking differences between the fish and poultry samples were as regards fat. The duck contained 28.43 per cent., the chicken and salmon nearly one-half, and the cod less than one-sixth of this amount. The amount of fat in fresh cod in fact has been shown by analyses elsewhere to be very small, averaging about .5 of one per cent. In this case, the higher fat content is due to the butter used in the frying.

As regards protein, the poultry was somewhat richer, the difference being about 6 per cent. The heat of combustion of the duck was highest, 4.244 calories per gram, that of the chicken and salmon about 2.6 calories per gram and that of the cod 1.616 calories per gram. The fact should not be lost sight of, however, that the composition of all these materials may be modified to a considerable extent, especially as regards water

* U. S. Dept. Agr., Division of Chemistry, Bul. 46, revised.

† For strict accuracy, the protein of bread should be taken as N × 5.70, and that of total feces as the sum of the nitrogen from bread × 5.70 and the nitrogen from other sources × 6.25. Such a change, however, would not appreciably affect the coefficients of availability, and the use of the factor 6.25 secures uniformity with previous work.

‡ Journ. Amer. Chem. Soc. Vol. 25, No. 7 (1903), p. 659.

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TABLE 12.

Percentage composition of food and feces and heat of combustion of food, feces and urine in digestion experiments Nos. 598–613.

Sample No.	KIND OF MATERIAL.	Water.	Protein (N×6.25)	Fat.	Carbohydrates.	Ash.	Heat of Combustion per Gram.
		%	%	%	%	%	Cal.*
3733	Salmon,	62.10	21.36	13.53	—	2.45	2.452
3749	Cod,	72.33	22.05	4.52	—	1.79	1.616
3741	Chicken,	57.20	28.57	11.60	—	2.40	2.780
3757	Duck,	41.75	27.15	28.43	—	1.87	4.247
3734	Bread,	35.85	8.75	3.91	50.56	.93	2.936
3750	Bread,	33.94	8.69	4.06	52.26	1.05	3.093
3742	Bread,	35.64	8.87	3.72	50.77	1.00	2.991
3758	Bread,	33.02	9.13	4.07	52.90	.88	3.080
3735	Milk,	87.78	3.15	1.73	6.99	.35	.697
3751	Milk,	87.46	3.08	3.71	5.04	.71	.725
3743	Milk,	87.40	3.20	3.73	4.95	.72	.726
3759	Milk,	86.13	2.97	4.01	6.11	.78	.798
3736	Butter,	11.96	.69	84.85	—	*a*2.50	7.517
3752	Butter,	13.83	.56	83.11	—	*a*2.50	7.678
3744	Butter,	9.71	.56	87.23	—	*a*2.50	7.626
3760	Duck-fat,	36.52	—	63.48	—	—	5.251
—	Sugar,	—	—	—	*a*100.00	—	*a*3.960
—	Rock-candy,	—	—	—	*a*100.00	—	*a*3.960
3738	Feces (partially dried),	6.15	32.00	22.68	20.17	19.00	5.494
3737	Feces (partially dried),	7.07	44.50	20.37	16.17	11.80	5.740
3740	Feces (partially dried),	5.11	29.38	24.40	19.04	22.07	5.389
3739	Feces (partially dried),	5.54	32.69	17.74	25.39	18.64	5.288
3754	Feces (partially dried),	7.91	46.50	21.07	11.57	12.95	5.439
3753	Feces (partially dried),	10.52	48.19	18.33	14.32	8.64	5.530
3756	Feces (partially dried),	7.69	32.31	22.41	17.39	20.20	5.135
3755	Feces (partially dried),	7.25	30.75	21.45	22.00	18.55	5.222
3746	Feces (partially dried),	11.63	37.19	17.28	18.79	15.11	5.353
3745	Feces (partially dried),	8.62	51.23	18.35	15.09	6.71	5.862
3748	Feces (partially dried),	3.96	27.13	22.27	26.36	20.28	5.764
3747	Feces (partially dried),	7.50	33.81	18.55	22.23	17.91	5.380
3762	Feces (partially dried),	7.35	42.88	31.08	8.95	9.74	6.027
3761	Feces (partially dried),	7.64	47.06	23.00	15.02	7.28	5.753
3764	Feces (partially dried),	5.70	35.88	26.18	15.79	16.45	5.462
3763	Feces (partially dried),	5.82	34.00	34.35	10.48	15.35	5.727
—	Urine, Exp. 598,	—	—	—	—	—	.153
—	Urine, Exp. 599,	—	—	—	—	—	.190
—	Urine, Exp. 600,	—	—	—	—	—	.103
—	Urine, Exp. 601,	—	—	—	—	—	.158
—	Urine, Exp. 602,	—	—	—	—	—	.187
—	Urine, Exp. 603,	—	—	—	—	—	.164
—	Urine, Exp. 604,	—	—	—	—	—	.109
—	Urine, Exp. 605,	—	—	—	—	—	.133

TABLE 12.—(*Continued*).

Sample No.	KIND OF MATERIAL.	Water.	Protein (N×6.25)	Fat.	Carbohydrates.	Ash.	Heat of Combustion per Gram.
		%	%	%	%	%	Cal.*
—	Urine, Exp. 606,	—	—	—	—	—	.132
—	Urine, Exp. 607,	—	—	—	—	—	.154
—	Urine, Exp. 608,	—	—	—	—	—	.133
—	Urine, Exp. 609,	—	—	—	—	—	.097
—	Urine, Exp. 610,	—	—	—	—	—	.152
—	Urine, Exp. 611,	—	—	—	—	—	.169
—	Urine, Exp. 612,	—	—	—	—	—	.121
—	Urine, Exp. 613,	—	—	—	—	—	.131

* The unit of energy is taken as the large Calorie, *i. e.*, the quantity of heat necessary to raise one kilogram of water one degree centigrade.
a Assumed.

content, by the method of preparation, though it seems probable that these analyses fairly represent the average composition of these materials as ordinarily eaten.

The milk samples were found to vary considerably, especially as regards fat. The reason for this is not entirely clear. It is possible that it is to be explained by incomplete mixing, either before delivery or in sampling.

The samples of bread and butter show as great uniformity as would be expected.

DATA OF THE EXPERIMENTS.

In these experiments no attempt was made to secure uniformity among the subjects as to either the kind or amount of food eaten from meal to meal. Thus, one of the subjects took no milk during most of the experiments, while with some of the other subjects it formed a very large part of the diet. Even the fish or poultry was occasionally omitted from a single meal. In all cases, however, it will be noted that the food under investigation made up a considerable proportion of the diet.

The subjects took their meals together in the laboratory, following as closely as possible their accustomed hours. In the experiments with salmon and chicken each subject, as already

explained, put an entire can of the salmon or chicken into a weighed bowl. After the removal of a portion for analysis, the bowl and contents were weighed. During the day the subject consumed as much of the material as he desired, the exact amounts being determined by difference by reweighing the bowl at the close of the day. A similar procedure was followed in the case of the duck.

The amounts eaten of cod, bread, milk, duck-fat and rock-candy were determined by direct weighing at each meal. Sugar was in most cases determined by weighing the bottle at the beginning and end of the experiment. Definite amounts of butter were weighed out when desired, and consumed from time to time.

All weighings taken were checked by another subject, thereby reducing the chances of error to a minimum.

TABLE 13.

Amounts of food, feces, and urine in digestion experiments Nos. 598–613.

Experiment No.	SUBJECT.	DIET.	FOOD EATEN.						Feces (partially dried).	Urine (third day).
			Fish or Poultry.	Bread.	Milk.	Butter.	Sugar.	Duck-fat.		
			Gms.	Gms.	Gms.	Gms.	Gms.	Gms.	Gms	Gms.
598	R.D.M.	Salmon, etc.	1138.9	923.5	2000.0	120.0	107.0	—	55.2	1039.2
599	H.C.M.	Salmon, etc.	1150.4	698.1	400.0	100.0	75.6	—	46.2	924.9
600	E.O.	Salmon, etc.	1272.8	900.0	2700.0	150.0	145.8	—	70.5	1490.5
601	E.M.S.	Salmon, etc.	1254.8	704.7	2700.0	50.0	107.3	—	64.9	1032.5
602	R.D.M.	Cod, etc.	891.4	950.0	1050.0	150.0	135.9	—	43.2	709.8
603	H.C.M.	Cod, etc.	1215.6	883.0	—	150.0	125.4	—	45.5	1142.7
604	E.O.	Cod, etc.	1365.9	675.0	2700.0	150.0	119.3	—	61.8	1685.5
605	E.M.S.	Cod, etc.	908.3	745.7	3600.0	115.0	192.2	—	58.3	*b*972.0
606	R.D.M.	Chicken, etc.	964.3	900.0	1800.0	125.0	153.0	—	47.1	1273.8
607	H.C.M.	Chicken, etc.	1029.6	788.2	—	120.6	76.9	—	56.7	1145.1
608	E.O.	Chicken, etc.	1328.0	500.0	2700.0	150.0	169.1	—	54.4	1362.0
609	E.M.S.	Chicken, etc.	1030.2	585.0	3200.0	50.0	159.2	—	47.1	1903.7
610	R.D.M.	Duck, etc.	795.3	800.0	800.0	—	188.7	409.4	50.7	809.5
611	H.C.M.	Duck, etc.	889.8	717.5	—	—	119.3	419.4	49.6	804.6
612	E.O.	Duck, etc.	1061.7	600.0	2100.0	—	105.8	234.5	59.6	1351.8
613	E.M.S.	Duck, etc.	747.5	724.8	3000.0	—	*a*235.3	188.3	60.4	1043.9

a Includes 31.5 grams of rock-candy.

b Lost about 25 grams by upsetting the bottle.

In Table 13 the amounts of the various foods eaten during the experiments are given, together with the weights of the partially dried feces and of the urine of the third day. The weights of fresh feces are not given since the analyses were made on the partially dried samples, and the computations of nutrients may be made from these data, irrespective of the total water content.

CALCULATION OF RESULTS.

The details of the separate digestion experiments are given in Tables 14 to 17 beyond. The kind and amounts of food eaten are first given as shown by Table 13. These amounts multiplied by their respective percentage composition and heats of combustion (taken from Table 12) give the weight of nutrients and energy in the total diet. In the same way the amounts of nutrients and energy in the partially dried feces are also computed.

Availability of nutrients of the total food.—The difference between the quantities of each nutrient in the total food and the amount of the corresponding nutrient in the feces is assumed to represent the amount digested. Dividing the amount digested by the corresponding amount eaten and multiplying by 100 give the proportion digested on a percentage basis, or as it is generally called, the coefficient of digestibility.

Strictly speaking, the results thus obtained do not represent actual or true digestibility, for the reason that the feces contain not only the portions of food that happen to escape digestion, but also other materials, such as the residues of digestive juices, bacteria, and intestinal debris, which collectively comprise what are commonly designated as metabolic products. To determine true digestibility it would be necessary to separate these metabolic products from the actually digested food, and deduct the ingredients of the latter from those of the food eaten. Thus far, however, no satisfactory method for separating the different constituents of the feces has been devised; consequently the actual digestibility of the food is not easily determined.

On the other hand, since the real object of digestion experiments such as are here reported is to determine what proportion of the food and its several ingredients is actually made available to the body for the purposes of nutrition, the metabolic

products may be considered as representing the cost of digestion in terms of food ingredients. From this point of view the total feces, including both these products and the undigested residue, may be considered as representing the portion of the food unavailable for the building of tissue and the yielding of energy. The difference between the total food and total feces may therefore be designated as the availability of the food. In this discussion, therefore, the term availability is so used, and the coefficients obtained as explained in detail are designated throughout as coefficients of availability.

Availability of nutrients of the fish or poultry alone.—Since the object of these experiments was to ascertain the availability of the fish and poultry alone, the coefficients for this portion of the diet must be determined. For this purpose, the remaining articles in the diet were those the coefficients of availability of which were already known from previous experiments. It was assumed that in the series here reported, their availability would be unchanged. By the use of these coefficients, therefore, it was possible to estimate the amounts of each nutrient of the feces derived from the foods other than fish or poultry. The remainder of the feces could be ascribed to the fish or poultry alone. From these amounts and corresponding weights of each nutrient in the fish or poultry eaten, the coefficients of availability of the fish or poultry could be determined as explained above for the total food.

In making these computations it was assumed that 88 per cent. of the protein of bread, and 97 per cent. of the protein of the milk and butter, and in all cases, 95 per cent. of the fat was available; or in other words, 12 per cent. of the protein of bread and 3 per cent. of the protein of milk and butter, together with 5 per cent. of the fat, was not available and would be found in the feces. This method may be illustrated by the use of figures from one of the experiments.

Thus, in experiment No. 558 (Table 14), with salmon, 80.8 grams of the total protein was supplied by the bread of which 12 per cent. or 9.7 grams was assumed to be not available and so found in the feces. The milk and butter supplied 63.8 grams of protein, of which 3 per cent. or 1.9 grams would be found in the feces. The total protein in the feces from the

food other than salmon was therefore 11.6, which, subtracted from the protein of the total feces, gave 6.1 grams as due to the salmon alone. The total protein supplied by the salmon was 243.3 grams, and the amount digested (243.3—6.1) was 237.2 grams. This quantity, divided by 243.3 grams and multiplied by 100 gave 97.49 per cent. as the coefficient of availability of the protein of salmon alone. The computations for fat were, when practicable, made in the same way.

It will be noted, however, that in several of the experiments the coefficient for fat was not computed. In such cases it was found that the figure obtained, in the manner outlined above, for feces from food other than poultry or fish was larger than the amount actually obtained by analysis for the total feces. The explanation of this discrepancy is to be found in the relatively small amounts of fat found in the feces as compared with the amounts supplied in the food. Under such conditions, a relatively small error in the assumed coefficient may make a considerable difference in the calculated result. In such cases, it has been assumed that the fat of the fish or poultry would have the same coefficient of availability as the total diet.

Since the poultry and fish contained no carbohydrates, it was assumed that the entire carbohydrates of the feces came from the remainder of the diet.

No coefficients of availability of the ash of the poultry and fish were computed, as the coefficients of availability of the ash of the other materials are not known with sufficient accuracy.

Coefficients of availability of energy.—The computations for the availability of the energy differ from the corresponding computations for the nutrients, in that the former show, not the actual availability of the energy to the body, but merely the quantity of energy in the food absorbed from the alimentary canal. It is known that a portion of the protein absorbed is not completely oxidized in the body, since it is excreted in forms like urea, uric acid, etc., which are capable of further oxidation outside the body. Account must therefore be taken of the energy lost to the body in these incompletely oxidized forms.

The method of computation adopted for the total diet was as follows: The energy of the food eaten and of the total feces was found by multiplying the weights of these materials by their heats of combustion per gram. The difference between the energy of food and feces represents the energy of the food as absorbed from the alimentary canal. The amount estimated to be lost to the body through the urine was found by multiplying the heat of combustion of the urine for the experiment by its weight. This gave the amount thus lost for a single day, and multiplied by three, the amount so lost for the entire experiment, since it was assumed that the loss would be constant from day to day. The amount thus lost was subtracted from the total amount absorbed, and the remainder, divided by the total energy of the food and multiplied by 100, gave the coefficients of the energy actually available to the body.

The computation of the available energy of the total diet in experiment No. 598 would therefore be as follows: The total energy of the food, 8224 calories, minus the energy of the feces, 303 calories, gives the energy of the food absorbed from the alimentary canal, 7921 calories. The weight of urine for the third day of the experiment was 1039.2 grams and its heat of combustion .153 calories per gram. The energy lost in the urine for the three days of the experiment was therefore 477 calories ($1039.2 \times .153 \times 3$). This amount, subtracted from the total amount absorbed, 7921 calories, divided by the total energy of the food, 8224 calories, and multiplied by 100, gives 90.52 per cent., the coefficient of availability of the energy of the total food.

The energy of the poultry and fish alone were computed according to the method described in detail in a previous report.* The energy of the feces from food other than poultry or fish was calculated from the weights of protein, fat and carbohydrates contained. The factors used were those elsewhere † computed as the heats of combustion of the nutrients in an ordinary mixed diet, viz., protein 5.65 calories, fat 9.4 calories, and carbohydrates 4.15 calories per gram. It was then assumed that the ratio of the energy of the total feces as calculated by the use of these factors to the energy of the total feces as

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* Storrs Expt. Sta. Rpt. 1904, pp. 191-3.

† Storrs Expt. Sta. Rpt. 1899, p. 104.

determined by the bomb calorimeter was the same as the ratio of the calculated energy of the feces from food other than fish or poultry to the required value.

Thus, in experiment No. 598, the computed energy of the total feces was 264 calories and the energy as determined from the heat of combustion 303 calories. The calculated value for the feces from food other than salmon was 192 calories. The proportion was therefore $264 : 303 = 192 : x$, in which case $x = 220$ calories.

The energy of the feces from salmon alone, 83 calories, was found by subtracting this figure from 303 calories. The proportion of energy in the salmon alone which was actually available to the body was then computed as in previous work by assuming that the energy lost to the body was equal to 1.25 times the weight of protein digested from the salmon alone (237.2 grams) or 297 calories. This amount, plus the 83 calories lost in the feces, subtracted from the total energy of the salmon (2793 calories), divided by 2793 calories and multiplied by 100, gave 86.39 per cent. the coefficient of availability of the energy of the salmon alone.

In the following pages the data of the four series of experiments are presented in detail.

EXPERIMENTS WITH SALMON.

The first series of experiments began with breakfast, Feb. 12, and continued three days with nine meals. The food under investigation was canned salmon, selected as a type of fish containing considerable fat. The remainder of the diet included bread, milk, butter, and sugar, though H. C. M. omitted milk, and E. M. S. butter from several of their meals.

The data of the four experiments with salmon are given in Table 14.

EXPERIMENTS WITH COD.

As a type of fish containing relatively little fat, fresh cod steaks were selected. The remainder of the diet included bread, milk, butter and sugar. One of the subjects, H. C. M., consumed no milk during the entire experiment, and the others omitted butter or sugar from one or more meals. R. D. M. consumed no cod at dinner and supper of the third day.

The experiments of this series began with breakfast, Feb. 18, and continued three days with nine meals.

The data of the four experiments with cod are given in Table 15.

EXPERIMENTS WITH CHICKEN.

As a type of relatively lean poultry, canned boned chicken was selected. The remainder of the diet included bread, milk, butter and sugar, though H. C. M. consumed no milk and E. M. S. omitted butter from several meals.

The series of experiments began with breakfast, Feb. 15, and continued three days, with nine meals.

The data of the four experiments with chicken are given in Table 16.

EXPERIMENTS WITH DUCK.

The final series of experiments was with roast duck, selected as a type of fat poultry. The remainder of the diet included bread, milk, sugar, and duck-fat. The duck-fat was that which cooked out of the duck during the roasting, and was eaten cold in the place of butter. H. C. M. consumed no milk during the experiment. On the first day of the experiment, but two meals were eaten, and E. O. restricted his diet to two meals each day. On the second day of the experiment E. M. S. consumed in the place of cane sugar a small amount of rock-candy.

The series of experiments began with breakfast, Feb. 21, and continued three days, with eight meals, except in the experiment with E. O. in which there was six meals.

The details of the four experiments with duck are given in Table 17.

TABLE 14.

Results of digestion experiments with salmon, Nos. 598–601.

DIET:—Salmon, Bread, Milk, Butter, and Sugar.

Sample No.		Weight of Material.	Protein.	Fat.	Carbo-hydrates.	Ash.	Energy.
	Experiment No. 598, with R. D. M.	Gms.	Gms.	Gms.	Gms.	Gms.	Cal.
	Food eaten:						
3733	Salmon,	1138.9	243.3	154.1	—	27.9	2793
3734	Bread,	923.5	80.8	36.1	466.9	8.6	2711
3735	Milk,	2000.0	63.0	34.6	139.8	7.0	1394
3736	Butter,	120.0	0.8	101.8	—	3.0	902
	Sugar,	107.0	—	—	107.0	—	424
	Total,	—	387.9	326.6	713.7	46.5	8224
3738	Feces from total food,	55.2	17.7	12.5	11.1	10.5	303
	Feces from food other than salmon,	—	11.6	8.6	11.1	—	220
	Feces from salmon alone,	—	6.1	3.9	—	—	83
	Amount digested from total food,	—	370.2	314.1	702.6	36.0	7921
	Amount digested from salmon alone,	—	237.2	150.2	—	—	2710
	Energy of urine from total food,	—	—	—	—	—	477
	Energy of urine from salmon alone,	—	—	—	—	—	297
			%	%	%	%	%
	Coefficients of availability:						
	Of total food,	—	95.44	96.17	98.44	77.42	90.52
	Of salmon alone,	—	97.49	97.47	—	—	86.39
	Experiment No. 599, with H. C. M.	Gms.	Gms	Gms.	Gms.	Gms.	Cal.
	Food eaten:						
3733	Salmon,	1150.4	245.7	155.6	—	28.2	2821
3734	Bread,	698.1	61.1	27.3	353.0	6.5	2050
3735	Milk,	400.0	12.6	6.9	28.0	1.4	279
3736	Butter,	100.0	0.7	84.9	—	2.5	752
	Sugar,	75.6	—	—	75.6	—	299
	Total,	—	320.1	274.7	456.6	38.6	6201
3737	Feces from total food,	46.2	20.6	9.4	7.5	5.5	265
	Feces from food other than salmon,	—	7.7	6.0	7.5	—	147
	Feces from salmon alone,	—	12.9	3.4	—	—	118
	Amount digested from total food,	—	299.5	265.3	449.1	33.1	5936
	Amount digested from salmon alone,	—	232.8	152.2	—	—	2703
	Energy of urine from total food,	—	—	—	—	—	527
	Energy of urine from salmon alone,	—	—	—	—	—	291
			%	%	%	%	%
	Coefficients of availability:						
	Of total food,	—	93.56	96.58	98.36	85.75	87.23
	Of salmon alone,	—	94.75	97.81	—	—	85.50

TABLE 14.—*(Continued)*.

Sample No.		Weight of Material.	Protein.	Fat.	Carbo-hydrates.	Ash.	Energy.
	Experiment No. 600, with E. O.	Gms.	Gms.	Gms.	Gms.	Gms.	Cal.
	Food eaten:						
3733	Salmon,	1272.8	271.9	172.2	—	31.2	3121
3734	Bread,	900.0	78.8	35.2	455.0	8.4	2642
3735	Milk,	2700.0	85.1	46.7	188.7	9.5	1882
3736	Butter,	150.0	1.0	127.3	—	3.8	1128
	Sugar,	145.8	—	—	145.8	—	577
	Total,	—	436.8	381.4	789.5	52.9	9350
3740	Feces from total food,	70.5	20.7	17.2	13.4	15.6	380
	Feces from food other than salmon,	—	12.1	10.5	13.4	—	254
	Feces from salmon alone,	—	8.6	6.7	—	—	126
	Amount digested from total food,	—	416.1	364.2	776.1	37.3	8970
	Amount digested from salmon alone,	—	263.3	165.5	—	—	2995
	Energy of urine from total food,	—	—	—	—	—	461
	Energy of urine from salmon alone,	—	—	—	—	—	329
			%	%	%	%	%
	Coefficients of availability:						
	Of total food,	—	95.26	95.49	98.30	70.51	91.01
	Of salmon alone,	—	96.84	96.11	—	—	85.42
	Experiment No. 601, with E. M. S.	Gms.	Gms.	Gms.	Gms.	Gms.	Cal.
	Food eaten:						
3733	Salmon,	1254.8	268.0	169.8	—	30.7	3077
3734	Bread,	704.7	61.7	27.6	356.3	6.6	2069
3735	Milk,	2700.0	85.1	46.7	188.7	9.5	1882
3736	Butter,	50.0	.3	42.4	—	1.3	376
	Sugar,	107.3	—	—	107.3	—	425
	Total,	—	415.1	286.5	652.3	48.1	7829
3739	Feces from total food,	64.9	21.2	11.5	16.5	12.1	343
	Feces from food other than salmon,	—	10.0	5.8	16.5	—	209
	Feces from salmon alone,	—	11.2	5.7	—	—	134
	Amount digested from total food,	—	393.9	275.0	635.8	36.0	7486
	Amount digested from salmon alone,	—	256.8	164.1	—	—	2943
	Energy of urine from total food,	—	—	—	—	—	489
	Energy of urine from salmon alone,	—	—	—	—	—	321
			%	%	%	%	%
	Coefficients of availability:						
	Of total food,	—	94.89	95.99	97.47	74.84	89.37
	Of salmon alone,	—	95.82	96.64	—	—	85.21

TABLE 15.

Results of digestion experiments with cod, Nos. 602-605.

DIET:—Cod, bread, milk, butter, and sugar.

Sample No.		Weight of Material.	Protein.	Fat.	Carbo-hydrates.	Ash.	Energy.
	Experiment No. 602, with R. D. M.	Gms.	Gms.	Gms.	Gms.	Gms.	Cal.
	Food eaten:						
3749	Cod, - - - - - -	891.4	196.6	40.3	—	16.0	1441
3750	Bread, - - - - - -	950.0	82.6	38.6	496.5	10.0	2938
3751	Milk - - - - - -	1050.0	32.3	39.0	52.9	7.5	761
3752	Butter, - - - - - -	150.0	.8	124.7	—	3.8	1152
	Sugar, - - - - - -	135.9	—	—	135.9	—	538
	Total, - - - - -	—	312.3	242.6	685.3	37.3	6830
3754	Feces from total food, - -	43.2	20.1	9.1	5.0	5.6	235
	Feces from food other than cod,	—	10.9	(10.1)	5.0	—	189
	Feces from cod alone, - -	—	9.2	—	—	—	46
	Amount digested from total food,	—	292.2	233.5	680.3	31.7	6595
	Amount digested from cod alone,	—	187.4	—	—	—	1395
	Energy of urine from total food,	—	—	—	—	—	398
	Energy of urine from cod alone, -	—	—	—	—	—	234
			%	%	%	%	%
	Coefficients of availability:						
	Of total food, - - - -	—	93.56	96.25	99.27	84.99	90.73
	Of cod alone, - - - -	—	95.32	*a*96.25	—	—	80.57
	Experiment No. 603, with H. C. M.	Gms.	Gms.	Gms.	Gms.	Gms.	Cal.
	Food eaten:						
3749	Cod, - - - - - -	1215.6	268.0	54.9	—	21.8	1964
3750	Bread, - - - - - -	883.0	76.7	35.9	461.5	9.3	2731
3752	Butter, - - - - - -	150.0	.8	124.7	—	3.8	1152
	Sugar, - - - - - -	125.4	—	—	125.4	—	497
	Total, - - - - -	—	345.5	215.5	586.9	34.9	6344
3753	Feces from total food, - -	45.5	21.9	8.3	6.5	3.9	252
	Feces from food other than cod,	—	9.2	8.0	6.5	—	169
	Feces from cod alone, - -	—	12.7	.3	—	—	83
	Amount digested from total food,	—	323.6	207.2	580.4	31.0	6092
	Amount digested from cod alone,	—	255.3	54.6	—	—	1881
	Energy of urine from total food,	—	—	—	—	—	562
	Energy of urine from cod alone, -	—	—	—	—	—	319
			%	%	%	%	%
	Coefficients of availability:						
	Of total food, - - - -	—	93.66	96.15	98.89	88.82	87.17
	Of cod alone, - - - -	—	95.26	99.45	—	—	79.53

TABLE 15.—*Continued.*

Sample No.		Weight of Material.	Protein.	Fat.	Carbo-hydrates.	Ash.	Energy.
	Experiment No. 604, with E. O.	Gms.	Gms.	Gms.	Gms.	Gms.	Cal.
	Food eaten:						
3749	Cod - - - - - -	1365.9	301.2	61.7	—	24.4	2207
3750	Bread, - - - - - -	675.0	58.7	27.4	352.8	7.1	2088
3751	Milk, - - - - - -	2700.0	83.2	100.2	136.1	19.2	1958
3752	Butter, - - - - - -	150.0	.8	124.7	—	3.8	1152
	Sugar, - - - - - -	119.3	—	—	119.3	—	472
	Total, - - - - -	—	443.9	314.0	608.2	54.5	7877
3756	Feces from total food, - -	61.8	20.0	13.8	10.7	12.5	317
	Feces from food other than cod,	—	9.5	12.6	10.7	—	240
	Feces from cod alone, - -	—	10.5	1.2	—	—	77
	Amount digested from total food,	—	423.9	300.2	597.5	42.0	7560
	Amount digested from cod alone,	—	290.7	60.5	—	—	2130
	Energy of urine from total food,	—	—	—	—	—	551
	Energy of urine from cod alone,	—	—	—	—	—	263
			%	%	%	%	%
	Coefficients of availability:						
	Of total food, - - -	—	95.49	95.61	98.24	77.06	88.98
	Of cod alone, - - - -	—	96.51	98.06	—	—	80.06
	Experiment No. 605, with E. M. S.	Gms.	Gms.	Gms.	Gms.	Gms.	Cal.
	Food eaten:						
3749	Cod, - - - - - -	908.3	200.3	41.1	—	16.3	1468
3750	Bread, - - - - - -	745.7	64.8	30.3	389.7	7.8	2306
3751	Milk, - - - - - -	3600.0	110.9	133.6	181.4	25.6	2610
3752	Butter, - - - - - -	115.0	.6	95.6	—	2.9	883
	Sugar, - - - - - -	192.2	—	—	192.2	—	761
	Total, - - - - -	—	376.6	300.6	763.3	52.6	8028
3755	Feces from total food, - -	58.3	17.9	12.5	12.8	10.8	304
	Feces from food other than cod, -	—	11.1	(13.0)	12.8	—	266
	Feces from cod alone, - -	—	6.8	—	—	—	38
	Amount digested from total food,	—	358.7	288.1	750.5	41.8	7724
	Amount digested from cod alone,	—	193.5	—	—	—	1430
	Energy of urine from total food,	—	—	—	—	—	388
	Energy of urine from cod alone,	—	—	—	—	—	242
			%	%	%	%	%
	Coefficients of availability:						
	Of total food, - - -	—	95.25	95.84	98.32	79.47	91.38
	Of cod alone, - - -	—	96.61	*a*95.84	—	—	80.93

a Coefficient assumed to be that of total food as explained on page 127.

TABLE 16.

Results of digestion experiments with chicken, Nos. 606–609.

DIET.—Chicken, bread, milk, butter, and sugar.

Sample No.		Weight of Material.	Protein.	Fat.	Carbo-hydrates.	Ash.	Energy.
	Experiment No. 606, with R. D. M.	Gms.	Gms.	Gms.	Gms.	Gms.	Cal.
	Food eaten:						
3741	Chicken, - - - - -	964.3	275.5	111.9	—	23.1	2681
3742	Bread, - - - - - -	900.0	79.8	33.5	456.9	9.0	2692
3743	Milk, - - - - - -	1800.0	57.6	67.1	89.1	13.0	1307
3744	Butter, - - - - - -	125.0	.7	109.0	—	3.1	953
	Sugar, - - - - - -	153.0	—	—	153.0	—	606
	Total, - - - - -	—	413.6	321.5	699.0	48.2	8239
3746	Feces from total food, - -	47.1	17.5	8.1	8.9	7.1	252
	Feces from food other than chicken,	—	11.7	(10.5)	8.9	—	240
	Feces from chicken alone, - -	—	5.8	—	—	—	12
	Amount digested from total food,	—	396.1	313.4	690.1	41.1	7987
	Am't digested from chicken alone,	—	269.7	—	—	—	2669
	Energy of urine from total food,	—	—	—	—	—	504
	Energy of urine f'm chicken alone,	—	—	—	—	—	337
			%	%	%	%	%
	Coefficients of availability:						
	Of total food, - - - -	—	95.77	97.48	98.73	85.27	90.82
	Of chicken alone, - - - -	—	97.90	a97.48	—	—	86.98
	Experiment No. 607, with H. C. M.	Gms.	Gms.	Gms.	Gms.	Gms.	Cal.
	Food eaten:						
3741	Chicken, - - - - -	1029.6	294.2	119.4	—	24.7	2862
3742	Bread, - - - - - -	788.2	69.9	29.3	400.2	7.9	2358
3744	Butter, - - - - - -	120.6	.7	105.2	—	3.0	920
	Sugar, - - - - - -	76.9	—	—	76.9	—	305
	Total, - - - - -	—	364.8	253.9	477.1	35.6	6445
3745	Feces from total food, - -	56.7	29.0	10.4	8.6	3.8	332
	Feces from food other than chicken,	—	8.4	6.7	8.6	—	163
	Feces from chicken alone, - -	—	20.2	3.7	—	—	169
	Amount digested from total food,	—	335.8	243.5	468.5	31.8	6113
	Am't digested from chicken alone,	—	274.0	115.7	—	—	2693
	Energy of urine from total food,	—	—	—	—	—	529
	Energy of urine f'm chicken alone,	—	—	—	—	—	343
			%	%	%	%	%
	Coefficients of availability:						
	Of total food, - - - -	—	92.05	95.90	98.20	89.33	86.64
	Of chicken alone, - - - -	—	93.13	96.90	—	—	82.11

TABLE 16.—*Continued.*

Sample No.		Weight of Material.	Protein.	Fat.	Carbo-hydrates.	Ash.	Energy.
	Experiment No. 608, with E. O.	Gms.	Gms.	Gms.	Gms.	Gms.	Cal.
	Food eaten:						
3741	Chicken,	1328.0	379.4	154.0	—	31.9	3692
3742	Bread,	500.0	44.4	18.6	253.9	5.0	1496
3743	Milk,	2700.0	86.4	100.7	133.7	19.4	1960
3744	Butter,	150.0	.8	130.9	—	3.8	1144
	Sugar,	169.1	—	—	169.1	—	670
	Total,	—	511.0	404.2	556.7	60.1	8962
3748	Feces from total food,	54.4	14.8	12.1	14.3	11.0	314
	Feces from food other than chicken,	—	7.9	(12.5)	14.3	—	270
	Feces from chicken alone,	—	6.9	—	—	—	44
	Amount digested from total food,	—	496.2	392.1	542.4	49.1	8648
	Am't digested from chicken alone,	—	372.5	—	—	—	3648
	Energy of urine from total food,	—	—	—	—	—	543
	Energy of urine f'm chicken alone,	—	—	—	—	—	465
			%	%	%	%	%
	Coefficients of availability:						
	Of total food,	—	97.11	97.01	97.43	81.70	90.44
	Of chicken alone,	—	98.18	*a*97.01	—	—	86.21
	Experiment No. 609, with E. M. S.	Gms.	Gms.	Gms.	Gms.	Gms.	Cal.
	Food eaten:						
3741	Chicken,	1030.2	294.3	119.5	—	24.7	2863
3742	Bread,	585.0	51.9	21.8	297.0	5.9	1750
3743	Milk,	3200.0	102.4	119.4	158.4	23.0	2323
3744	Butter,	50.0	.3	43.6	—	1.3	381
	Sugar,	159.2	—	—	159.2	—	630
	Total,	—	448.9	304.3	614.6	54.9	7947
3747	Feces from total food,	47.1	15.9	8.7	10.5	8.4	253
	Feces from food other than chicken,	—	9.3	(9.2)	10.5	—	215
	Feces from chicken alone,	—	6.6	—	—	—	38
	Amount digested from total food,	—	433.0	295.6	604.1	46.5	7694
	Am't digested from chicken alone,	—	287.7	—	—	—	2825
	Energy of urine from total food,	—	—	—	—	—	554
	Energy of urine f'm chicken alone,	—	—	—	—	—	360
			%	%	%	%	%
	Coefficients of availability:						
	Of total food,	—	96.46	97.14	98.29	84.70	89.85
	Of chicken alone,	—	97.76	*a*97.14	—	—	86.10

a Coefficient assumed to be that of total food as explained on page 127.

TABLE 17.

Results of digestion experiments with duck, Nos. 610–613.

DIET:—Duck, Bread, Milk, Duck-fat, Sugar, and Rock-candy.

Sample No.		Weight of Material.	Protein.	Fat.	Carbo-hydrates.	Ash.	Energy.
	Experiment No. 610, with R. D. M.	Gms.	Gms.	Gms.	Gms.	Gms.	Cal.
	Food eaten:						
3757	Duck,	795.3	215.9	226.1	—	14.9	3378
3758	Bread,	800.0	73.0	32.6	423.2	7.0	2464
3759	Milk,	800.0	23.8	32.1	48.9	6.2	638
3760	Duck-fat,	409.4	—	259.9	—	—	2150
	Sugar,	188.7	—	—	188.7	—	747
	Total,	—	312.7	550.7	660.8	28.1	9377
3762	Feces from total food,	50.7	21.7	15.8	4.5	4.9	306
	Feces from food other than duck and duck-fat,	—	9.5	3.2	4.5	—	109
	Feces from duck and duck-fat alone,	—	12.2	12.6	—	—	197
	Amount digested from total food,	—	291.0	534.9	656.3	23.2	9071
	Amount digested from duck and duck-fat alone,	—	203.7	473.4	—	—	5331
	Energy of urine from total food,	—	—	—	—	—	369
	Energy of urine from duck alone,	—	—	—	—	—	255
			%	%	%	%	%
	Coefficients of availability:						
	Of total food,	—	93.06	97.13	99.32	82.56	92.80
	Of duck and duck-fat alone,	—	94.35	97.41	—	—	91.82
	Experiment No. 611, with H. C. M.	Gms.	Gms.	Gms.	Gms.	Gms.	Cal.
	Food eaten:						
3757	Duck,	889.8	241.6	253.0	—	16.6	3779
3758	Bread,	717.5	65.5	29.2	379.6	6.3	2210
3760	Duck-fat,	419.4	—	266.2	—	—	2202
	Sugar,	119.3	—	—	119.3	—	472
	Total,	—	307.1	548.4	498.9	22.9	8663
3761	Feces from total food,	49.6	23.3	11.4	7.4	3.6	285
	Feces from food other than duck and duck-fat,	—	7.9	1.5	7.4	—	94
	Feces from duck and duck-fat alone,		15.4	9.9	—	—	191
	Amount digested from total food,	—	283.8	537.0	491.5	19.3	8378
	Amount digested from duck and duck-fat alone,	—	226.2	509.3	—	—	5790
	Energy of urine from total food,	—	—	—	—	—	408
	Energy of urine from duck alone,	—	—	—	—	—	283
			%	%	%	%	%
	Coefficients of availability:						
	Of total food,	—	92.41	97.92	98.52	84.28	92.00
	Of duck and duck-fat alone,	—	93.63	98.09	—	—	92.07

TABLE 17.—(*Continued*).

Sample.		Weight of Material.	Protein.	Fat.	Carbo-hydrates.	Ash.	Energy.
	Experiment No. 612, with E. O.	Gms.	Gms.	Gms.	Gms.	Gms.	Cal.
	Food eaten:						
3757	Duck,	1061.7	288.3	301.8	—	19.9	4509
3758	Bread,	600.0	54.8	24.4	317.4	5.3	1848
3759	Milk,	2100.0	62.4	84.2	128.3	16.4	1676
3760	Duck-fat,	234.5	—	148.9	—	—	1231
	Sugar,	105.8	—	—	105.8	—	419
	Total,	—	405.5	559.3	551.5	41.6	9683
3764	Feces from total food,	59.6	21.4	15.6	9.4	9.8	326
	Feces from food other than duck and duck-fat,	—	8.5	5.4	9.4	—	147
	Feces from duck and duck-fat alone,	—	12.9	10.2	—	—	179
	Amount digested from total food,	—	384.1	543.7	542.1	31.8	9357
	Amount digested from duck and duck-fat alone,	—	275.4	440.5	—	—	5561
	Energy of urine from total food,	—	—	—	—	—	491
	Energy of urine from duck alone,	—	—	—	—	—	344
			%	%	%	%	%
	Coefficients of availability:						
	Of total food,	—	94.72	97.21	98.30	76.44	91.56
	Of duck and duck-fat alone,	—	95.53	97.74	—	—	90.89
	Experiment No. 613, with E. M. S.	Gms.	Gms.	Gms.	Gms.	Gms.	Cal.
	Food eaten:						
3757	Duck,	747.5	202.9	212.5	—	14.0	3175
3758	Bread,	724.8	66.2	29.5	383.4	6.4	2232
3759	Milk,	3000.0	89.1	120.3	183.3	23.4	2394
3760	Duck-fat,	188.3	—	119.5	—	—	989
	Sugar,	203.8	—	—	203.8	—	807
	Rock-candy,	31.5	—	—	31.5	—	125
	Total,	—	358.2	481.8	802.0	43.8	9722
3763	Feces from total food,	60.4	20.5	20.7	6.3	9.3	346
	Feces from food other than duck and duck-fat,	—	10.6	7.5	6.3	—	161
	Feces from duck and duck-fat alone,	—	9.9	13.2	—	—	185
	Amount digested from total food,	—	337.7	461.1	795.7	34.5	9376
	Amount digested from duck and duck-fat alone,	—	193.0	318.8	—	—	3979
	Energy of urine from total food,	—	—	—	—	—	410
	Energy of urine from duck alone,	—	—	—	—	—	241
			%	%	%	%	%
	Coefficients of availability:						
	Of total food,	—	94.28	95.70	99.21	78.77	92.22
	Of duck and duck-fat alone,	—	95.12	96.03	—	—	89.77

TABLE 18.

Summary of coefficients of availability of nutrients and energy.

Expt. No.	SUBJECT.		Protein.	Fat.	Carbo-hydrates.	Ash.	Energy.
		Total diet.	%	%	%	%	%
598	R. D. M.	Salmon, etc., - - -	95.44	96.17	98.44	77.42	90.52
599	H. C. M.	Salmon, etc., - - -	93.56	96.58	98.36	85.75	87.23
600	E. O.	Salmon, etc., - - -	95.26	95.49	98.30	70.51	91.01
601	E. M. S.	Salmon, etc., - - -	94.89	95.99	97.47	74.84	89.37
		Average, - - -	94.79	96.06	98.14	77.13	89.53
602	R. D. M.	Cod, etc., - - - -	93.56	96.25	99.27	84.99	90.73
603	H. C. M.	Cod, etc., - - - -	93.66	96.15	98.89	88.82	87.17
604	E. O.	Cod, etc., - - - -	95.49	95.61	98.24	77.06	88.98
605	E. M. S.	Cod, etc., - - - -	95.25	95.84	98.32	79.47	91.38
		Average, - - -	94.49	95.96	98.68	82.59	89.57
606	R. D. M.	Chicken, etc., - - -	95.77	97.48	98.73	85.27	90.82
607	H. C. M.	Chicken, etc., - - -	92.05	95.90	98.20	89.33	86.64
608	E. O.	Chicken, etc., - - -	97.11	97.01	97.43	81.70	90.44
609	E. M. S.	Chicken, etc., - - -	96.46	97.14	98.29	84.70	89.85
		Average, - - -	95.35	96.88	98.16	85.25	89.44
610	R. D. M.	Duck, etc., - - -	93.06	97.13	99.32	82.56	92.80
611	H. C. M.	Duck, etc., - - -	92.41	97.92	98.52	84.28	92.00
612	E. O.	Duck, etc., - - -	94.72	97.21	98.30	76.44	91.56
613	E. M. S.	Duck, etc., - - -	94.28	95.70	99.21	78.77	92.22
		Average, - - -	93.62	96.99	98.84	80.51	92.15
		Fish and poultry alone.					
598	R. D. M.	Salmon, etc., - - -	97.49	97.47	—	—	86.39
599	H. C. M.	Salmon, etc., - - -	94.75	97.81	—	—	85.50
600	E. O.	Salmon, etc., - - -	96.84	96.11	—	—	85.42
601	E. M. S.	Salmon, etc., - - -	95.82	96.64	—	—	85.21
		Average, - - -	96.23	97.01	—	—	85.63
602	R. D. M.	Cod, etc., - - - -	95.32	*a*96.25	—	—	80.57
603	H. C. M.	Cod, etc., - - - -	95.26	99.45	—	—	79.53
604	E. O.	Cod, etc., - - - -	96.51	98.06	—	—	80.06
605	E. M. S.	Cod, etc., - - - -	96.61	*a*95.84	—	—	80.93
		Average, - - -	95.93	97.40	—	—	80.27
606	R. D. M.	Chicken, etc., - - -	97.90	*a*97.48	—	—	86.98
607	H. C. M.	Chicken, etc., - - -	93.13	96.90	—	—	82.11
608	E. O.	Chicken, etc., - - -	98.18	*a*97.01	—	—	86.21
609	E. M. S.	Chicken, etc., - - -	97.76	*a*97.14	—	—	86.10
		Average, - - -	96.74	97.13	—	—	85.35
610	R. D. M.	Duck, etc., - - -	94.35	97.41	—	—	91.82
611	H. C. M.	Duck, etc., - - -	93.63	98.09	—	—	92.07
612	E. O.	Duck, etc., - - -	95.53	97.74	—	—	90.89
613	E. M. S.	Duck, etc., - - -	95.12	96.03	—	—	89.77
		Average, - - -	94.66	97.32	—	—	91.14

a Assumed as explained on page 127.

SUMMARY AND DISCUSSION OF RESULTS.

In Table 18, above, are summarized the coefficients of availability as found in the preceding experiments. The upper portion of the table gives the coefficients for the nutrients and energy of the total diet, and the lower portion, the coefficients for protein, fat and energy of the fish and poultry alone.

Results for total diet.—In all the experiments, the coefficients for fat and carbohydrates for all four subjects are in close agreement, the greatest variation being in the experiments with duck, in which H. C. M. digested 97.92 per cent. of the fat, and E. O. 95.70 per cent., a difference of 2.22 per cent. In most cases, the variation among the different subjects is less than 1 per cent.

As regards protein and energy, greater variation is found. In the experiments with chicken, the coefficients were for E. O., 97.11 per cent. of the protein and 90.44 per cent. of the energy, while for H. C. M. the coefficients were 92.41 per cent. and 86.64 per cent. respectively, a difference of 4.70 per cent. of protein and 3.80 per cent. of the energy. In general, the agreement was as close as could be expected.

The variations among the different diets were even smaller than those between individual experiments of the same series. The diet seemed to be very thoroughy digested in every case. In some instances, the subjects did not find it particularly palatable, but no difference as to completeness of digestion is to be noted. This would tend further to confirm the results of many experiments both in this country and abroad which indicate that the influence of palatability upon completeness of digestion is less important than is commonly supposed.

Results for the fish and poultry alone.—As already explained in detail, the availability of the fish and poultry alone was computed by assuming that the availability of the remaining articles of the diet would be the same as in other experiments with such materials. The results thus obtained are summarized in the lower portion of Table 18. As has already been explained, in several cases the computations for fat could not be made. In such experiments, the coefficient for the fish or poultry was assumed to be that found for the entire diet.

It will be noted that the separate experiments of each series agree on the whole very closely. The greatest variations are found in the series with chicken, in which the extremes were 98.18 and 93.15 per cent. for protein, and 86.98 and 82.11 per cent. for energy. In most of the other instances, the agreement was within 1 to 2 per cent.

As regards the different series, the variations of the coefficients for fat are remarkably small, the extreme difference in the average being but .39 per cent. It is to be questioned whether such close agreement was not more or less accidental. Apparently, however, the presence of large amounts of fat did not appreciably affect its digestibility.

The average availability of the protein of the different foods varied less than that of the same protein by the four subjects. For the cod and salmon the coefficient was about 96 per cent., for chicken a little higher, and for duck somewhat lower than this figure.

The greatest variation will be noted as regards energy. For salmon and chicken, the coefficients are about 85 per cent., for cod 80 per cent. and for duck 91 per cent. Reference to the composition table shows that the heat of combustion and fat content were highest in the duck sample, about equal for the salmon and chicken, and least in the case of the cod. This may be an indication that the availability of the energy is highest in foods containing a large amount of fat, though the data at hand are not sufficient to warrant too sweeping deductions.

A comparison of the coefficients of availability of the poultry and fish with those of other common foods is given in Table 19, which follows.

TABLE 19.

Availability of nutrients and energy of poultry, fish, and other common foods.

KIND OF FOOD.	Protein.	Fat.	Energy.
	%	%	%
Salmon,	96.2	97.0	85.6
Cod,	95.9	97.4	80.3
Chicken,	96.7	97.1	85.4
Duck,	94.7	97.3	91.1
Beef,	97.6	96.5	—
Veal,	98.0	98.9	—
Mutton,	97.1	98.5	—
Pork (fresh ham),	99.1	99.4	—
Milk,	92.2	96.3	91.3
White Bread,	88.1	—	92.0

CONCLUSION.

From the results of sixteen experiments in which canned salmon, fresh cod, canned chicken, and roast duck made up in turn a considerable portion of the diet, it appears that these foods are very completely digested, the coefficients of availability being approximately those previously found for other animal foods. The foods containing a considerable proportion of fat were apparently as completely digested as those in which the percentage of fat was relatively small. The number of kinds of poultry and fish investigated and the number of experiments carried on with each, are too small to warrant further conclusions.

DIETARY STUDIES OF A WEEK'S WALKING TRIP.

BY H. L. KNIGHT.*

The studies summarized in the following report comprise investigations as to the kind and amount of food eaten by two young men of sedentary habit while on a week's walking trip through the White Mountains.

The studies were incidental to the trip itself, which was taken as a means of spending a few days of the summer vacation out of doors in an unfamiliar part of the country. In pursuance of this plan, camp equipage was included in the outfit, and the entire food supply, aside from about two days' rations taken from home at the start, was purchased in as portable a form as possible along the way.

Since the manner of life, and the diet as well, were quite different from those to which the subjects were ordinarily accustomed, it was considered of interest to record the data which are presented in detail beyond.

So far as is known to the writer no studies of precisely this nature have as yet been published. Observations have been made of the food consumption of professional pedestrians, notably Weston, as well as soldiers on the march, bicyclists, college boat crews and others engaged for short periods at severe muscular exercise. Numerous investigations have also been conducted in which subjects without previous training have walked from twenty to fifty miles per day. Thus, in 1882, North, in an experiment reported elsewhere,† walked on single days distances of from thirty to forty-seven miles carrying a load of twenty-seven pounds. In most of these researches, however, the diet was restricted as to either the kind or amount of food eaten, and the results, while of value as an index to the body

* The writer desires to express his indebtedness to Mr. C. H. Collester for his assistance in acting as a subject, and for many valuable suggestions incorporated in the report.

† U. S. Dept. Agr. Office of Experiment Stations Bul. 45. pp. 120, 31.

requirements, afford little information as to the selection of food materials under conditions such as are here presented. An estimate of the food purchased by a canoeing party in Maine has been reported in a compilation of dietary studies by Atwater,* but the amounts of food eaten were not ascertained and the work as a whole is considered unreliable. Data regarding the food consumption of subjects voluntarily walking considerable distances for several days, living entirely out of doors, and depending for their food supply on what could be procured from day to day, appear to be lacking.

THE SUBJECTS.

The subjects were two men, 24 years of age, engaged at sedentary occupations for the entire year except for the summer vacation. One, hereafter referred to as C. H. C., was a college instructor, and the other, H. L. K., the author of this report, was an employee of the U. S. Department of Agriculture and engaged for about eight hours per day in editorial work pertaining to the nutrition investigations. Both ordinarily took comparatively little exercise, though both played tennis and walked short distances as opportunity permitted. Neither subject had ever taken any walk of so extensive a nature, nor had had practical experience in camping or of living for more than a few meals on other than the ordinary diet. Previous to the trip the food consumption of both subjects had been noticeably small.

THE TRIP.

The trip began with a railroad journey of 150 miles to the heart of the White Mountain district and continued for seven days, return being made on the eighth by a similiar trip by rail. In the interval a stretch of about fifty miles was traversed on foot. There were also many detours to points of interest, including several mountain climbs.

The mileage walked was recorded by a pedometer, and showed a total of 157.75 miles, or 22.54 miles per day. It should be stated, however, that in principle the pedometer is a register not of distance but of the number of steps taken, and its accuracy in measuring distance depends upon the uniformity

* Conn. (Storrs) Sta. Rpt. 1902–3, p. 135.

of the length of step. The pedometer used was adjusted for a standard length of step (28 inches), which a test over a known distance had shown to be that ordinarily taken. It seems probable however, that on one or two occasions, as on a particularly severe mountain climb, and again on a jaunt down a railroad track along the ties, the step was perceptibly shortened and the distance measured correspondingly overestimated. Moreover, since the pedometer was carried not merely while on the road, but during the entire day, it registered the many short steps incidental to the building of the camp, preparation of meals, etc. As nearly as could be estimated these were sufficient to average from three to four miles of the total reading for each day, though it is doubtful if an equivalent of more than two or three miles was actually covered in this way. Making due allowance for these inaccuracies, however, it still does not seem possible that the actual mileage could have fallen below 140 miles, or an average of twenty miles per day.

As previously stated, camp equipage was carried sufficient for shelter, preparation of food, etc. Each man's burden was weighed at a time when it was reduced to a minimum, and found to weigh twenty-three pounds. With the amount of food usually carried, this was frequently increased to at least twenty-five pounds per man.

ROUTINE.

The daily program was in general as follows: The subjects rose about daybreak (5 o'clock), took a bath in a nearby stream, had breakfast about 7 o'clock, and broke camp as soon as the luggage was sufficiently dry, which was usually between 8 and 9 o'clock. The average rate of walking was about three miles per hour, with frequent stops for water, rest or observation of the scenery. About 1 o'clock a halt of an hour was made for dinner, after which the walking continued till about 5 o'clock, when a convenient location was sought for a camp. This found, the tent was pitched, and supper prepared and eaten. By the time this was finished and the day's records completed, it was usually dark (8 o'clock) and the subjects turned in at once.

SELECTION AND PREPARATION OF FOOD MATERIALS.

The selection of food materials was governed very largely by circumstances. Rather concentrated food was given the preference, since it was obviously of advantage to carry articles with the least bulk and weight. Goods in packages were preferred to the same articles in bulk. Perishable materials were purchased in as small quantities as possible, and prepared foods were preferred to raw foods. At the same time variety was sought so far as possible, and, when practicable, comparatively bulky foods, like milk and bananas, were used freely. Again, the choice was restricted by necessity to the limited assortment of articles on sale along the route. During the week but one village containing a bakery was passed through, and the remainder of the time it was necessary to rely very largely upon wayside stores, containing, in most cases, little more than a few kinds of fancy crackers, sweet chocolate and birch beer. In a single instance, a summer hotel supplied a camper's lunch. It had been supposed that milk could be readily obtained, in which case it would doubtless have been made use of very largely. It was found, however, that farmhouses were few and for long distances missing altogether. As a result milk was purchased on but three of the eight days. Red raspberries and dwarf blueberries were found by the roadside on several days and were eaten when desired. Where further choice of materials was possible, the deciding test was usually the personal preference of the subjects. The cost of the articles was never a prominent factor, as economy was by no means a primary feature of the trip.

As previously stated, about two days' rations were carried from home. This food was largely in the form of sandwiches, as these were easily prepared and well adapted to the conditions.

The choice of articles for a given meal was decided largely by the same considerations as governed their original selection. Perishable materials, especially meats, were consumed as quickly as possible after opening the original package. Bulky articles likewise were disposed of as speedily as practicable.

Foods requiring cooking were eaten at night and in the morning, as no fire was kindled at noon. Since, as already explained, most of the food materials were purchased ready to

eat, the preparation of food was a comparatively simple matter. Bacon was fried for two meals, and several mornings beef tea was made from the prepared extract, and chocolate from milk chocolate to which was sometimes added several malted milk tablets. The entire amount thus prepared was divided between the two subjects and consumed at once. The amounts of all other food materials consumed at a given meal were regulated entirely by the appetites of the subjects.

From these explanations, it will be apparent that it was in no sense the purpose of the investigation to follow any particular theories as to either kind or amount of food eaten. In fact, aside from the weighing of the food, every effort was made to live exactly as if no dietary study were in progress.

DETAILS OF THE DIETARY STUDIES.

The method employed in conducting these dietary studies consisted in brief in determining the amounts of each food material eaten by each subject during each meal of the trip. From these data, the percentage composition and fuel value of the food materials, and the coefficients of availability, were computed the amounts of total and available nutrients and energy consumed by each subject throughout the experiment. The price paid for each article of food was likewise recorded, and served as a basis for observations as to their relative economy.

Weighing of foods.—The amounts eaten of all solid food materials were for the most part determined by weighing each man's portion on a small hand balance. This balance was considered sensitive to 10 milligrams with a load of 100 grams, but no weight greater than 70 grams was ever put upon it, and weights were taken only to grams as the general conditions of experimenting were not sufficiently exact to warrant greater accuracy. In the case of fancy cookies and similar articles made in molds of the same size and presumably of uniform weight, the above method was simplified by weighing a considerable number of each, assuming that the average weight thus obtained was representative of the entire package, and thereafter recording merely the number eaten. The same plan was also followed for the raspberries and blueberries as a means of obviating many tedious weighings.

All weights and measurements were made and recorded by the writer, who, however, checked his work by noting the weights unused at each weighing. Since the amounts weighed at a time were comparatively small, the chance for serious error was not so great as might appear. A further check, though a rough one, was afforded by securing as accurately as possible the original weight of each package at the time of purchase and then noting the weight of the empty package. As in most cases there was no waste, the difference was obviously the weight of food consumed.

The amounts consumed of liquids, including milk, chocolate, beef tea, birch beer and root beer were estimated by measurement, and the weights then computed. A large amount of water also was drunk, of which no account was taken.

Composition of food materials.—Theoretically, in studies of this kind, each food material used should be sampled and analyzed. This was obviously impracticable under the circumstances, and recourse was had to analyses of similar food materials compiled elsewhere.* It is recognized that the composition of such materials varies widely. This is especially true in the case of cooked foods, because of differences in the recipes used in their preparation. Consequently, the results of these studies must be considered less reliable than those based on actual sampling and analysis. Nevertheless, they serve the purpose for which they were made, and give a fair indication of the food consumption of the subjects.

The following table gives the percentage composition and energy of each material as employed in the computations. The table also includes the amount paid per pound, the materials taken from home at the start being estimated at the prevailing White Mountain prices.

A study of this table reveals anew the fact that the cost of food is a very unreliable indication of its nutritive value. Thus, the malted milk tablets, a proprietary preparation for which extraordinary claims are made and selling at the rate of $3.50 per pound, actually contain somewhat less of both protein and energy than the deviled ham which was procured in

* U. S. Dept. Agr., Office of Experiment Stations Buls. 28, 152; Division of Chemistry Bul. 13, part 9; Conn. (New Haven) Stations Rpt. 1903, Lab. Inland Rev. Dept., Canada, Bul. 63.

TABLE 20.

Percentage of nutrients, amount of available energy (fuel value) per gram, and cost per pound of food eaten.

	Protein N x 6.25.	Fat.	Carbo-hydrates.	Energy (fuel value) per gram.	Cost per pound.
	%	%	%	Cals.	$
Beef, sandwich meat,	28.0	11.0	—	2.17	.20
Beef, tongue, canned,	19.5	23.2	—	2.95	.27
Beef, extract,	7.5	.6	—	.96	2.27
Bacon, fried, as eaten,	22.2	33.2	—	4.00	1.06
Ham, deviled, canned,	19.0	34.1	—	3.94	.33
Sausage, pork, canned, edible portion,	16.6	24.8	—	2.98	.33
Chicken, canned,	20.8	30.0	—	3.65	.96
Sardines, canned, edible portion,	23.0	19.7	—	2.78	.63
Eggs, boiled, edible portion,	13.2	12.0	—	1.70	.22
Cheese, full cream,	25.9	33.7	2.4	4.30	.34
Milk, whole,	3.3	4.0	5.0	.72	.04
Bread, white, home made,	9.1	1.6	53.3	2.70	.10
Bread, whole wheat,	9.7	.9	49.7	2.51	.10
Crackers, butter,	9.6	10.1	71.6	4.26	.25
Crackers, cheese filled,	9.7	12.1	69.7	4.38	.43
Saltines,	10.6	12.7	68.5	4.42	.31
Crispanola,*	10.7	5.0	78.7	4.11	.35
Cake, chocolate layer,	6.2	8.1	64.1	3.63	.15
Cup cakes,	5.9	9.0	68.5	3.90	.09
Cake, sponge,	6.3	10.7	65.9	3.95	.15
Cookies, molasses,	7.2	8.7	75.7	4.21	.23
Cookies, sugar,	7.0	10.2	73.2	4.23	.11
Doughnuts,	6.7	21.0	53.1	4.41	.11
Sultanas,	6.0	7.4	71.0	3.74	.23
Candy (lime drops, gum drops),	—	—	96.0	3.93	.41
Sugar, maple,	—	—	82.8	3.39	.20
Bananas, edible portion,	1.3	.6	22.0	1.01	.12
Huckleberries,	.6	.6	16.6	.76	.00†
Raspberries, red,	1.0	—	12.6	.56	.00†
Raisins, seeded,	2.6	3.3	76.1	3.54	.10
Peanut butter,	29.3	46.5	17.1	6.22	.32
Chocolate milk,	9.1	31.3	54.3	5.32	1.03
Malted milk tablets,	15.2	2.7	76.1	3.89	3.50
Beer (birch and root),	—	—	11.2	.45	.08

* Crispanola is a confection consisting chiefly of popcorn, but containing molasses, peanuts and cocoanut. The composition assumed is that of popcorn.
† Not purchased.

packages for 33 cents per pound. The deviled ham likewise supplied about the same nutrients and energy as the fried bacon and at one-third the cost. This was due to the fact that while the original cost was about the same, there was no waste with the ham whereas a large share of the bacon was cooked out in the frying and not utilized. The beef extract, sold at $2.27

per pound, contained not more than one-fourth to one-third of the energy of the various kinds of bread, crackers, and pastry bought at from 10 to 25 cents per pound. It also contained less protein, and this chiefly in the form of nitrogenous extractive matter with a very small actual nutritive value as compared with that of bread protein.

It should be borne in mind that in many instances the high prices given in the table may be attributed to the fact that the articles were purchased in limited quantities and in packages, factors which would tend to increase the cost. The difference in price of the molasses and sugar cookies is thus explained, since the former were bought in small packages and the latter in bulk. In general it was found that prices for the class of goods purchased were no higher in the White Mountain district than elsewhere.

As regards the nutrients and energy furnished by the different foods, it may be said that the various meats, the sardines and eggs were high in protein, and the crackers, pastry and sugars, high in energy. The fried bacon and deviled ham, cheese, peanut butter, chocolate and malted milk tablets were high in both protein and energy and may be considered concentrated foods. The deviled ham, cheese and peanut butter were also among the least expensive foods purchased.

Availability of nutrients and energy.—Since only that portion of the food which is assimilated by the body can be used for the building of tissue and the yielding of energy, it is upon the amounts of nutrients and energy available for these purposes, rather than the total amounts as shown by analyses, that their value depends. The figures given in Table 20 for energy (fuel value) actually represent the quantities available, but those given for protein, fats and carbohydrates do not. Since, however, the chief function of the fats and carbohydrates is to serve as sources of energy, the proportion which they individually supply signify very little, and their recalculation is therefore not here attempted. To obtain the amounts of available protein, the various food materials have, for convenience, been grouped under ten general classes, namely, meats, fish, eggs, dairy products, breads, pastry, sugars, fruits, nuts, and beverages. The amounts of available protein have then been

computed for each of these classes, by means of factors—the so-called coefficients of availability. These have been derived from the results of actual digestion experiments,* and are given in Table 21 below. The figures show what percentages of the total protein are available for body use.

TABLE 21.

Coefficients of availability of protein of different classes of food materials.

CLASS OF FOOD.	Protein.
	%
Meats,	97
Fish,	97
Eggs,	97
Dairy products,	97
Bread, crackers, etc.,	85
Pastry, etc.,	85
Sugars, etc.,	—
Fruits,	85
Nuts,	80
Beverages,	97

Weights of the subjects.—The weights of both subjects were taken on ordinary platform scales weighing to pounds and ounces, at 5 P. M. of the afternoon preceding the trip and at the same hour of the day of the return. During the trip the only opportunity afforded was met with on the fifth day when the weights were secured at 11 A. M. The figures thus obtained are given in the sections dealing with the separate studies.

Number and scope of the studies.—Two studies were completed, one with each subject. Each began with supper of the first day and ended with dinner of the eighth day. The total number of regular meals was twenty-one, corresponding to seven full days. In addition, considerable quantities of food were consumed from time to time between meals.

In the sections following, the data for each study are presented in detail. The menu showing the kind and amount of food consumed at each meal is first given. It will be noted that in addition to the three regular meals other items frequently

* Storrs Experiment Station Report 1899, p. 73.

appear under the heading "lunch." These refer to materials, such as berries, birch beer, etc., consumed as already explained from time to time during the day, and are grouped in this way solely for convenience.

Following the menus is a table showing the amounts consumed of each food material for the entire period, the quantities of total and available nutrients and energy obtained from each class of foods, and the cost.

DIETARY STUDY NO. 459.

The subject of this study was C. H. C., employed as a college instructor about nine months in the year. Previous to the trip, he had spent about two months of his vacation playing tennis, walking, etc., the total daily exercise estimated as corresponding to a walk of from six to eight miles per day. He was of athletic build, weighing normally with clothing about 175 pounds, was six feet two inches tall, and at the time of the study was in perfect health. His weight as taken on the day preceding the trip was 174 pounds, on the fifth day, 165 pounds, and on the final day, 166.5 pounds, a net loss of 7.5 pounds during the trip.

MENU.

August 7. Supper: Egg sandwiches (whole wheat bread, 150 grams; eggs 78 grams); milk, 363 grams; chocolate.*

August 8. Breakfast: Beef sandwiches (whole wheat bread, 100 grams; beef, 70 grams); sultanas, 34 grams; chocolate;* malted milk tablets, 2 grams.

Dinner: Beef sandwiches (whole wheat bread, 150 grams; beef, 105 grams); sultanas, 45 grams.

Lunch: Lime drops, 43 grams; malted milk tablets, 1 gram.

Supper: Beef sandwiches (whole wheat bread, 50 grams; white bread, 72 grams; beef, 65 grams); sultanas, 11 grams; chocolate;* malted milk tablets, 5 grams.

August 9. Breakfast: Egg sandwiches (white bread, 72 grams; eggs, 34 grams); eggs, 52 grams; cup cakes, 50 grams; doughnuts, 38 grams.

Lunch: Lime drops, 65 grams; birch beer, 227 grams; chocolate, 16 grams; malted milk tablets, 33 grams.

Dinner: Egg sandwiches (white bread, 54 grams; eggs, 26 grams); cheese, 19 grams; sponge cake, 53 grams.

Supper: Canned tongue, 110 grams; cheese crackers, 48 grams; chocolate, 17 grams; malted milk tablets, 3 grams.

August 10. Breakfast: Canned tongue, 101 grams; cheese crackers, 50 grams; chocolate, 16 grams.

* A cake of chocolate weighing 110 grams was consumed prior to lunch August 9.

Lunch: Milk, 227 grams; gum drops, 30 grams; raspberries, 37 grams; birch beer, 908 grams.

Dinner: Butter crackers, 65 grams; cheese crackers, 14 grams; crispanola, 65 grams; bananas, 160 grams; peanut butter, 37 grams; root beer, 227 grams.

Supper: Canned chicken, 64 grams; butter crackers, 65 grams; crispanola, 31 grams; molasses cookies, 29 grams; maple sugar, 30 grams; peanut butter, 17 grams.

August 11. *Breakfast:* Butter crackers, 43 grams; molasses cookies, 34 grams; bananas, 104 grams; peanut butter, 28 grams; chocolate 16 grams.

Lunch: Huckleberries, 4 grams; birch beer, 681 grams.

Dinner: Butter crackers, 14 grams; saltines, 53 grams; molasses cookies, 14 grams; sultanas, 34 grams; maple sugar, 23 grams; huckleberries, 9 grams; peanut butter, 60 grams.

Supper: Deviled ham, 78 grams; butter crackers, 108 grams; saltines, 30 grams; sultanas, 67 grams; maple sugar, 76 grams.

August 12. *Breakfast:* Fried bacon, 21 grams; deviled ham, 16 grams; butter crackers, 85 grams; sultanas, 58 grams; maple sugar, 55 grams.

Lunch: Huckleberries, 32 grams; raspberries, 138 grams; birch beer, 454 grams; chocolate, 8 grams.

Dinner: Sausages, 105 grams; cheese, 18 grams; butter crackers, 5 grams; saltines, 68 grams; maple sugar, 89 grams.

Supper: Deviled ham sandwiches (white bread, 127 grams; deviled ham, 60 grams); eggs, 54 grams; sugar cookies, 38 grams; cup cakes, 67 grams; maple sugar, 65 grams; huckleberries, 34 grams; chocolate 16 grams.

August 13. *Breakfast:* Beef extract, 5 grams; fried bacon, 18 grams; deviled ham sandwiches (white bread, 101 grams; deviled ham, 45 grams); cheese, 12 grams; saltines, 15 grams; gum drops, 53 grams; maple sugar, 40 grams.

Lunch: Milk, 227 grams; huckleberries, 66 grams; raspberries, 12 grams; root beer, 227 grams; chocolate, 20 grams.

Dinner: Sardines, 108 grams; milk, 227 grams; white bread, 282 grams; saltines, 16 grams; sugar cookies, 34 grams; raisins, 50 grams.

Supper: White bread, 94 grams; cup cakes, 28 grams; sultanas, 99 grams, raisins, 91 grams.

August 14. *Breakfast:* Beef extract, 13 grams; sausage, 50 grams; eggs, 31 grams; white bread, 221 grams; sultanas, 34 grams, raisins, 43 grams; root beer, 227 grams.

Dinner: Sultanas; 63 grams; raisins, 71 grams; chocolate, 48 grams.

TABLE 22.

Kind, amount and cost of food eaten, and amounts of total nutrients and energy, and available protein and energy supplied in dietary study No. 459.

Kind, Amount and Cost of Different Food Materials.	Cost.	Amounts of Total Nutrients and Energy. Protein.	Fat.	Carbohydrates.	Energy.†	Amounts Available. Protein.	Energy.
ANIMAL FOOD.	$	Gms.	Gms.	Gms.	Cal.	Gms.	Cals.
Beef, sandwich meat, 240 gms., 11 c.; tongue, 211 gms., 12 c.; beef, extract, 18 gms., 9 c.; bacon, fried, 39 gms., 9 c.; ham, deviled, 199 gms., 15 c,; sausage, 155 gms., 11 c.; chicken, 64 gms., 14 c. Total meats,	.81	195.2	213.9	—	—	189.3	2796
Sardines, 108 gms.,	.15	24.8	21.3	—	—	24.1	300
Eggs, boiled, 269 gms.,	.13	35.5	32.3	—	—	34.4	457
Cheese, 82 gms., 6 c.; milk, 1044 gms., 9 c. Total dairy products,	.15	55.7	69.4	54.2	—	54.0	1105
Total animal food,	1.24	311.2	336.9	54.2	—	301.8	4658
VEGETABLE FOOD.							
Bread, white, 1023 gms., 23 c.; bread, whole wheat, 450 gms., 10 c.; crackers, butter, 385 gms., 21 c.; crackers, cheese filled, 112 gms., 11 c; saltines, 182 gms., 13 c.; crispanola, 96 gms., 7 c. Total bread, crackers, etc.,	.85	214.3	100.9	1323.1	—	182.2	7222
Cup cakes, 145 gms., 3 c.; cake, sponge, 53 gms., 2 c.; cookies, molasses, 77 gms., 4 c.; cookies, sugar, 72 gms., 2 c.; doughnuts, 38 gms., 1 c.; sultanas, 445 gms., 22 c. Total pastry, etc.,	.34	51.6	73.7	581.4	—	43.9	3226
Candy, 191 gms., 17 c.; sugar, maple, 378 gms., 17 c. Total sugars, etc.,	.34	—	—	496.4	—	—	2032
Bananas, 264 gms., 7 c.; huckleberries, 145 gms., 0*; raisins, seeded, 255 gms., 6 c.; raspberries, red, 187 gms., 0.* Total fruits and berries,	.13	12.8	10.9	299.9	—	10.9	1385
Peanut butter, 142 gms., 10 c.,	.10	41.6	66.0	24.3	—	33.3	883
Beer, birch and root, 2951 gms., 50 c.; chocolate, 267 gms., 60 c.; malted milk tablets, 44 gms., 34 c. Total beverages,	1.44	31.0	84.8	509.0	—	30.1	2919
Total vegetable food,	3.20	351.3	336.3	3234.1	—	300.4	17667
Total food,	4.44	662.5	673.2	3288.3	—	602.2	22325
Average per day,	.63	94.6	96.2	469.8	—	86.0	3189

* Not purchased. † Not computed.

DIETARY STUDY NO. 460.

The subject of this study was H. L. K., 24 years of age, employed at editorial work. He took a small amount of muscular exercise mostly in walking and tennis, the total comprising a probable maximum equivalent of a five mile walk daily. His general health had been good to within a month of the experiment when a slight nervous trouble had resulted in less exercise than usual. A week of his vacation had elapsed before the trip was undertaken, and at that time he felt nearly as well as usual, though his weight, with clothing normally 135 pounds, had fallen to 124.5 pounds on the day preceding the trip. On the fifth day, a further drop to 119.75 pounds was noted. The final day showed no further change, making a net loss of 4.75 pounds during the trip.

MENU.

August 7. Supper: Egg sandwiches (whole wheat bread, 50 grams; eggs, 26 grams); milk, 545 grams; chocolate.*

August 8. Breakfast: Beef sandwiches (whole wheat bread, 50 grams; beef, 35 grams); sultanas, 22 grams; chocolate;* malted milk tablets, 2 grams.

Lunch: Lime drops, 8 grams; malted milk tablets, 3 grams.

Dinner: Beef sandwiches (whole wheat bread, 100 grams; beef, 70 grams); sultanas, 23 grams.

Supper: Beef sandwiches (white bread, 72 grams; beef, 30 grams); cheese, 36 grams; sultanas, 11 grams; chocolate;* malted milk tablets, 5 grams.

August 9. Breakfast: Egg sandwiches (white bread, 36 grams; eggs, 17 grams); eggs, 58 grams; cheese, 34 grams; doughnuts, 37 grams.

Lunch: Lime drops, 14 grams; malted milk tablets, 8 grams.

Dinner: Egg sandwiches (white bread, 54 grams; eggs, 26 grams); cheese, 19 grams; chocolate cake, 58 grams.

Supper: Canned tongue, 110 grams; cheese crackers, 11 grams; chocolate, 17 grams; malted milk tablets, 3 grams.

August 10. Breakfast: Canned tongue, 101 grams; cheese crackers, 20 grams; chocolate, 6 grams.

Lunch: Milk, 227 grams; huckleberries, 18 grams; raspberries, 33 grams; birch beer, 908 grams.

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* A cake of chocolate weighing 110 grams was consumed prior to lunch August 9.

Dinner: Cheese crackers, 17 grams; butter crackers, 43 grams; bananas, 94 grams; peanut butter, 17 grams.

Supper: Canned chicken, 78 grams; butter crackers, 21 grams; crispanola, 35 grams; molasses cookies, 14 grams; maple sugar, 28 grams.

August 11. Breakfast: Butter crackers, 43 grams; bananas, 114 grams; peanut butter, 26 grams; chocolate, 16 grams.

Lunch: Huckleberries, 5 grams; birch beer, 681 grams.

Dinner: Saltines, 23 grams; molasses cookies, 10 grams; sultanas, 34 grams; maple sugar, 21 grams; huckleberries, 4 grams; peanut butter, 35 grams.

Supper: Deviled ham, 82 grams; saltines, 38 grams; sultanas, 22 grams; maple sugar, 23 grams.

August 12. Breakfast: Fried bacon, 13 grams; deviled ham, 15 grams; butter crackers, 35 grams: sultanas, 22 grams; maple sugar, 36 grams.

Lunch: Huckleberries, 20 grams; raspberries, 102 grams; birch beer, 454 grams.

Dinner: Sausage, 105 grams; cheese, 21 grams; butter crackers, 5 grams; saltines, 30 grams.

Supper: Deviled ham sandwiches (white bread, 89 grams; deviled ham, 45 grams); eggs, 52 grams; maple sugar, 31 grams.

August 13. Breakfast: Beef extract, 5 grams; fried bacon, 12 grams; eggs, 42 grams; cheese, 11 grams; saltines, 15 grams; bananas, 101 grams; raspberries, 10 grams.

Lunch: Milk, 227 grams; huckleberries, 50 grams; raspberries, 28 grams.

Dinner: Milk, 227 grams; bread, 82 grams; sugar cookies, 39 grams; raisins, 39 grams.

Supper: Bread, 94 grams; sugar cookies, 26 grams; raisins, 66 grams.

August 14. Breakfast: Beef extract, 13 grams; sausage, 17 grams; bread, 117 grams; raisins, 34 grams.

Dinner: Butter crackers, 25 grams; raisins, 64 grams; chocolate, 48 grams.

TABLE 23.

Kind, amount and cost of food eaten, and amounts of total nutrients and energy, and available protein and energy supplied in dietary study No. 460.

Kind, Amount and Cost of Different Food Materials.	Cost.	Amounts of Total Nutrients and Energy. Protein.	Fat.	Carbohydrates.	Energy.†	Amounts Available. Protein.	Energy.
	$	Gms.	Gms.	Gms.	Cal.	Gms.	Cals.
ANIMAL FOOD.							
Beef, sandwich meat, 135 gms., 6 c.; tongue, 211 gms., 12 c.; beef, extract, 18 gms., 9 c.; bacon, fried, 25 gms., 6 c.; ham, deviled, 142 gms., 10 c.; sausage, 122 gms., 9 c.; chicken, 78 gms., 16 c. Total meats,	.68	149.4	174.4	—	—	144.9	2240
Eggs, boiled, 204 gms.,	.10	26.9	24.5	—	—	26.1	347
Cheese, 121 gms., 9 c.; milk, 1226 gms., 11 c. Total dairy products,	.20	71.8	89.8	64.2	—	69.6	1403
Total animal food,	.98	248.1	288.7	64.2	—	240.6	3990
VEGETABLE FOOD.							
Bread, white, 544 gms., 12 c.; bread, whole wheat, 200 gms., 4 c.; crackers, butter, 172 gms., 9 c.; crackers, cheese filled, 48 gms., 5 c.; saltines, 106 gms., 7 c.; crispanola, 35 gms, 3 c. Total bread, crackers, etc.,	.40	105.0	49.0	646.1	—	89.3	3527
Cake, chocolate layer, 58 gms., 2 c.; cookies, molasses, 24 gms., 1 c.; cookies, sugar, 65 gms., 2 c.; doughnuts, 37 gms., 1 c.; sultanas, 134 gms., 7 c. Total pastry, etc.,	.13	20.4	31.1	217.7	—	17.3	1251
Candy, 22 gms., 2 c.; sugar, maple, 139 gms., 6 c. Total sugars, etc.,	.08	—	—	136.2	—	—	557
Bananas, 309 gms., 8 c.; huckleberries, 97 gms., 0;* raisins, seeded, 203 gms., 4 c.; raspberries, red, 173 gms., 0.* Total fruits and berries,	.12	11.6	9.2	260.4	—	9.9	1202
Peanut butter, 78 gms., 5 c.,	.05	22.9	36.3	13.3	—	18.3	485
Beer, birch, 2043 gms., 35 c.; chocolate, 197 gms., 45 c.; malted milk tablets, 21 gms., 16 c. Total beverages,	.96	21.1	62.3	351.8	—	20.5	2049
Total vegetable food,	1.74	181.0	187.9	1625.5	—	155.3	9071
Total food,	2.72	429.1	476.6	1689.7	—	395.9	13061
Average per day,	.39	61.3	68.1	241.4	—	56.6	1866

* Not purchased. † Not computed.

RESULTS OF THE DIETARY STUDIES.

From Tables 22 and 23 above, a comparative estimate of the dietaries of the two subjects may be obtained. It will be noted that in study No. 459, C. H. C. consumed daily an average of 86.0 grams of protein and 3189 calories of energy in forms available to the body. The protein was obtained in about equal portions from the animal and vegetable food, the chief sources being the meats, bread and crackers. These foods, together with the pastry and beverages, likewise furnished the bulk of the energy, four-fifths of it, however, being of vegetable origin. The cost was 63 cents per day, of which 28 per cent. was for animal and 72 per cent. for vegetable food. One-third of the total cost was expended for beverages, though these furnished but 5 per cent. of the available protein and 13 per cent. of the available energy.

The daily quantities of available protein and energy consumed by H. L. K., in study No. 460 were 56.6 grams and 1866 calories respectively. Larger percentages came from animal food than in the preceding study, 60 per cent. of the protein and 30 per cent. of the energy being thus obtained, as compared with 50 and 20 per cent. in study No. 459. This difference may be attributed very largely to circumstances already explained. The amount of meats on hand was usually limited and it was the custom to make a nearly equal division, while the vegetable food was used to make up the remainder of the meal according to the dictates of appetite. The cost in this dietary was 39 cents per day, of which 25 per cent. was for meats, 15 per cent. for bread and crackers and 35 per cent. for beverages.

The total cost of the diet in the case of H. L. K. was two-thirds of that of C. H. C. This is partly due to slight differences in their respective diets, though the chief explanation is to be sought in the much smaller food consumption of the former.

Errors in the selection of food materials.—As regards the selection of food materials, no serious errors appear to have been made, though a much larger return was obtained from some foods than from others and had economy been sought some money could doubtless have been saved by replacing some of

the foods by similar cheaper materials. Thus, the money expended for the canned chicken and fried bacon would have bought much larger quantities of the deviled ham or canned tongue. The cheese and peanut butter were economical foods under the circumstances and might have been used more largely. The most expensive materials purchased were the beverages. The malted milk tablets in particular yielded a very small amount of nutrients in proportion to their cost, and it is highly probable that a package of cereal coffee or some similar article could have been substituted to good advantage. The large expenditure for the beef extract, the birch and root beer, and to a lesser degree, of the chocolate, must be justified because of considerations other than nutritive value. The expenditures for the more expensive meats and crackers are likewise chiefly warranted because of the obvious desirability of securing variety in the diet and of providing food which was relished by the subjects. The amount expended, $3.08 per man for the entire week, is no larger than would be expected under the conditions.

Adequacy of the diet.—The true criterion of the value of a diet is manifestly not its cost but its adequacy for the body needs. Reference has already been made to the marked disparity in the food consumption of the two subjects. This is in part accounted for by the fact that C. H. C. was a man eight inches taller and 50 pounds heavier than his companion. That this is not a complete explanation, however, is shown by Table 24 which follows. In this table are summarized the total daily quantities of available protein and energy obtained by each subject and the amounts thus furnished per kilo of their initial body weights. For purposes of further comparison, similar data from other studies and the commonly accepted dietary standards for men of sedentary occupation and of light to moderate muscular work are also included.

Per kilo of body weight, the daily available protein obtained by C. H. C. was 1.1 grams and that by H. L. K. 1.0 gram, while the available energy was respectively 40 and 33 calories. The reason for this difference is not entirely clear, as the conditions were in most respects the same for both subjects. The weighing of the food and recording of data, however, fell

TABLE 24.

Amounts of available Protein and Energy per day and per kilo of body weight.

SUBJECT.	Protein.	Energy.	Body Weight.	Per Kilo of Body Weight. Protein.	Per Kilo of Body Weight. Energy.
	Gms.	Cals.	Kilos.	Gms.	Cals.
C. H. C.,	86.0	3189	79.1	1.1	40
H. L. K.,	56.6	1866	56.4	1.0	33
Average of ten Harvard students,[1]	78.1	2720	59.8	1.3	45
Professional pedestrian, Weston,[2]	196.0	4065	60.0	3.3	68
Professional pedestrian, Schmell,[3]	164.5	—	65.8	2.5	—
Average of 7 Russian students at rest,[4]	100.0	—	—	—	—
Average of 7 Russian students walking,[4]	107.0	—	—	—	—
Canoeing party in Maine,[5]	158.0*	5145*	—	—	—
Dietary Standards.					
Man with sedentary occupation,	92.0	2700	68.0	1.4	40
Man with light to moderate muscular work,	103.0	3050	68.0	1.5	45

1 U. S. Dept. Agr., Office of Experiment Stations Bul. 152, p. 56.
2 Conn. (Storrs) Sta. Report, 1902-3, p. 135.
3 U. S. Dept. Agr., Office of Experiment Stations Bul. 45, p. 119; Flint, Relation of Urea to Exercise, p. 19.
4 U. S. Dept. Agr., Office of Experiment Stations Bul. 45, p. 121.
5 Conn. (Storrs) Sta. Report, 1902-3, p. 135.
* Food purchased.

wholly on H. L. K. As this work was of necessity done almost entirely at meal times, he frequently ate more hastily than was his usual habit. This may have tended to decrease his food consumption to a certain extent, and the writer is inclined to believe such was the case.

Comparison with the other data included in Table 24 indicates that the food consumption of both subjects was small. Per kilo of body weight, the amounts of protein and energy obtained by the two were, in fact, lower than even the figures obtained with the Harvard students with little exercise, or the amounts called for by the commonly accepted standards for men with sedentary occupations.

That the food consumption was adequate is doubtful. The record of body weights as given on pages 152 and 155 shows a loss in weight in the first five days of 9 pounds for C. H. C.

and of 4.75 pounds for H. L. K. For the remainder of the study there was a gain of 1.5 pounds with C. H. C. or a net loss of 7.5 pounds for the whole period, and no further change in the case of H. L. K. To be sure, it is well known that body weight alone is by no means a reliable indicator of actual body conditions. Loss in weight may be of little significance if due to increased elimination of water, and an apparent gain may be a real loss, as in the replacement of fat by water. The loss of weight at the start is not surprising since the suddenly increased muscular exertion would naturally draw upon the reserve materials for the body for a time regardless of the diet. At the same time, so large a loss tends to confirm the belief that the diet was not large enough. A study of the menus shows that more food was eaten on the last days of the trip. This also would indicate that the body has been insufficiently supplied. Further evidence is found in the fact, mentioned beyond, that both subjects recovered normal weight in a few days after the trip had ended.

As no means were available for estimating the outgo of nitrogen, no determination of the gain or loss of this element was possible, but there is further evidence that in the case of H. L. K. the amount of energy supplied was insufficient. A few months before, several experiments had been made with this subject in which it was shown by means of the respiration calorimeter that his normal heat production, while sitting as quietly as possible, was about 90 calories per hour. Long series of similar experiments with other subjects show that the heat elimination during sleep was at least 50 calories per hour. Assuming that nine hours were spent in sleep the heat production per day of this subject when at rest becomes $9 \times 50 + 15 \times 90 = 450 + 1350 = 1800$ calories.

Using Haughton's* formulas for the work done in walking both on horizontal and inclined planes, a rough estimate, which however, is a minimum figure, of 963,225 foot pounds per day may be obtained. This divided by 3,088, the mechanical equivalent of 1 calorie, gives as the consequent heat production, 312 calories, making a minimum of 2,112 calories actually required as compared with 1,866 furnished by the food.

* Principles of Animal Mechanics, pp. 57, 58.

Less complete data are at hand in the case of C. H. C., but from what is known of the heat elimination of other subjects of his weight, here also there must have been a considerable deficit.

While no definite information can be obtained as to the food consumption of either subject previous to the experiment, it is certain that their normal diet with only sedentary work was quite as large as when walking twenty miles a day. This seems rather surprising. Zasietsky,* however, in his experiments with the Russian students summarized in Table 24 above, obtained similar results. In his experiments seven students after two or three days of absolute rest (lying down) walked for several days from 9 A. M. to 9 P. M. with short intervals of rest. No marked influence of exercise upon the amount of food consumed was noted, though he attempts no explanation for this. In the present investigation it seems most probable that the necessity of economizing in bulk and weight of the food carried produced a tendency to economize unconsciously in the food consumed.

On the return from the journey both subjects resumed their ordinary diets and their usual daily occupations. Both immediately noted unusually good appetites and while the food was not weighed the consumption unquestionably increased. H. L. K. regained his initial weight in five days and C. H. C. in four days. At the end of a week the latter reported further slight gains. Aside from occasional discomfort due to climatic conditions, no ill effects other than loss in weight were noticed at any time during the journey. Both subjects felt better when they returned than when they started, and their subsequent physical condition has revealed no detrimental results traceable to the trip.

SUMMARY.

In these studies, two young men of sedentary habit walked without previous training an average distance of twenty miles per day for seven consecutive days, each carrying about twenty-five pounds of luggage. Notwithstanding the unwonted physical exertion, their food consumption did not increase, though

* U. S. Dept. Agr. Office of Experiment Stations Bul. 45, pp. 121 and 131.

the diet furnished considerably less protein and energy than are called for by the commonly accepted dietary standards for men at light to moderate muscular work. No positive ill effects were noted, except a loss in weight of about five pounds, and this was regained in less than a week after the return from the journey.

The studies may be considered of interest as an indication of the nutritive value of the food materials available to the pedestrian carrying his daily food supply. The foods selected were on the whole well adapted to the conditions, though it is a question whether some of the less concentrated foods might not have been more largely included to advantage. In the attempt to reduce bulk and weight there was apparently a tendency to restrict unconsciously the food consumption as well, and perhaps to an undue extent. It is not probable that the amounts eaten were adequate for the body needs particularly as regards energy. The condition was therefore one of partial inanition, and so limited a diet could hardly have continued for any considerable period without serious injury. The studies well illustrate how in case of need the reserve forces of the body may be drawn upon for a short time without apparent detriment, as well as the necessity of continuing investigations of this nature for long periods before drawing definite conclusions.

STUDIES OF MARKET MILK.

BY W. A. STOCKING, JR.

The milk annually consumed in this country in its natural form is estimated to have a wholesale value of something over two millions of dollars. The enormous amount of milk which is represented by this money value is used as human food, and a greater or less part finds its way into practically every household in this country. It is easy to see, then, why there has been during the past few years such a general sentiment in favor of a better quality of milk for use in its natural form. This growing sentiment can be seen in the daily press, in the results of scientific investigations and in the individual demands of various households.

This desire for a better quality of milk is only one of the avenues through which the public is demanding better protection for its health. Pure food laws are no longer the exception and at present almost every article designed for human consumption is more or less thoroughly controlled by law and comes more or less completely under legal inspection. All of this is in perfect harmony with the increasing sanitary and scientific knowledge which has developed during the past few years. The public agitation in regard to the quality of the milk delivered to the consumer has not developed by itself but simply as one phase of the general demand for pure foods. Many milk consumers, especially in the cities, have come to realize that the ordinary milk which they are able to purchase in the market is not always what it should be from a sanitary standpoint and are demanding an article which they can safely use as food. As a result of this condition there is at the present time a limited amount of milk put upon the market which is produced under conditions much more sanitary than those under which the ordinary milk is produced. This means an increase in the cost of production and this grade of milk is usually sold

at a price much in advance of that asked for the ordinary milk. Milk produced under these conditions is sold under various names, such as "certified milk," "sanitary milk," and "clinical milk." Such milk is commonly recommended by physicians who from time to time inspect the farms where it is produced and test the milk for its germ content. Such milk commonly sells for a price so much higher than the ordinary milk that most people feel that they cannot afford to use it except where recommended by physicians for specific cases for the use of invalids or for infants. At the present time most of our states and cities have fairly satisfactory laws in regard to the chemical composition of milk sold within their territories and these laws are fairly well enforced by the health boards and milk inspectors. This insures to the consumer a reasonably good quality of milk so far as its chemical composition is concerned and the consumer need have but little fear of getting milk which does not come up to the local requirements so far as fat and total solids are concerned. These same local authorities also very carefully guard the consumer against the use of chemical preservatives in market milk within their jurisdiction. There may be, and frequently is, but little difference so far as chemical composition is concerned between the ordinary milk supply and that sold under the name of "sanitary" or "certified" milk. Both may be rich in milk fat and in solids and be free from any chemical preservatives, yet one may be a perfectly wholesome food while the other is decidedly unwholesome if not positively poisonous. The principal difference between these two grades lies in the sanitary conditions under which the milk has been produced and handled.

Bacteria content of market milk.—With the development of the science of bacteriology it has become possible to study the sanitary condition of the milk which is being daily consumed as human food. The health boards and other authorities are at present making a determined effort to ascertain the real condition of the milk which is delivered in our larger cities and in many instances the conditions brought to light by these examinations are appalling. Park* in New York found that "during the coldest winter weather the milk in New York

* The Bacterial Content of City Milk. H. W. Park, Science, Vol. 13, 1901, p. 322.

City averages about 250,000 bacteria per cubic centimeter. During cool weather about 2,000,000 and during hot weather about 5,000,000."

Slack* found that out of 2,394 samples of Boston milk, 42 per cent. showed a germ content of less than 100,000 bacteria per cubic centimeter; 29.75 per cent. was between 100,000 and 500,000; 9.75 per cent. between 500,000 and 1,000,000; 12.75 per cent. between 1,000,000 and 5,000,000; and 5 per cent. above 5,000,000. These counts were made during June, July, August, and September. The results of these tests show that 71.75 per cent. of all the samples taken contained a germ content below the Boston legal limit of 500,000 bacteria per cubic centimeter, while 27.50 per cent. were above this limit. These figures represented the milk as it reached the city of Boston.

Conn† found by a study of the milk delivered in the city of Middletown that the germ content of twenty-seven samples taken from different milkmen showed an average of 266,400 bacteria per cubic centimeter. The lowest number found in any sample was 8,100 and the highest 2,973,800.

Hellens‡ found by a study of market milk sold in Helsingfors that the milk contained "during the summer from 20,000 to 34,300,000 bacteria per cubic centimeter, the average being 4,745,000, while in the winter the bacteria content ranged from 70,000 to 18,630,000, and averaged 2,111,000. About 60 per cent. of the summer samples contained from 1,000,000 bacteria per cubic centimeter against 35 per cent. in the winter samples."

In a series of studies|| of the market milk sold in the city of Guelph, Harrison found that the germ content ranged from 121,000 to 1,200,000 per cubic centimeter. At the same time the milk produced at the College dairy ranged from 8,000 to 18,000 per cubic centimeter.

Out of 291 samples§ of milk purchased in the open market of Chicago during April, May, and June, 1904, Jordan found

* Am. Journal of Public Hygiene, Nov., 1904.

† Report of Storrs Experiment Station, 1902-3, p. 76.

‡ O. V. Hellens, Nord. Mejiri Tidn., 14, 1899.

|| Ontario Agricultural and Experiment Farm Report, 1896.

§ Health and Sanitation Committee of the Civic Federation of Chicago, 1904.

that "the average number of bacteria per cubic centimeter exceeded 9,000,000 in April, 10,000,000 in May, and 18,000,000 in June. The range in the different samples was from 10,000 to 74,000,000 per cubic centimeter. Only 1.4 per cent. of the total number of samples showed less than 50,000 bacteria per cubic centimeter."

Individual lots of milk frequently run much higher in bacteria than any of the figures given here. The number of bacteria per cubic centimeter is an indication of the care under which the milk has been produced and handled. There is, on the other hand, considerable milk sold especially in the smaller cities which has a much smaller germ content than the figures given.

De Schweinitz* tested thirty-two samples of milk taken from fifteen different dairy wagons as delivered in the city of Washington, D. C. Of these thirty-two samples one showed only about 2,500 bacteria per cubic centimeter, one 4,000, five others between 10,000 and 15,000, six between 30,000 and 50,000, and the remainder more than 50,000 per cubic centimeter, in several instances running above 115,000 bacteria per cubic centimeter.

When we compare these large numbers of bacteria which are found in milk at the time it is delivered to the consumers with the small numbers existing in the milk as it leaves the udder of the healthy cow (from a dozen or two to a few hundred per cubic centimeter) the contamination and improper treatment which takes place in the production and subsequent handling of the milk is apparent.

Bacterial content of sanitary milk.—In contrast to the numbers found in ordinary market milk it is interesting to note the numbers of bacteria found in the so-called "sanitary milk" as it reaches the consumer. De Schweinitz found that "sanitary milk" as delivered in Washington contained a bacterial content varying from 200 to 5,000 bacteria per cubic centimeter. Out of 135 samples examined only eleven showed a bacterial content of over 5,000 per cubic centimeter. As a result of his investigation De Schweinitz makes the following statement:

* A Report upon Examination of Milk. E. A. De Schweinitz, Annual Report of Bureau of Animal Industry, 1899, p. 148.

"The results of the examinations which we have made show that it is possible to keep the bacterial content down below 50,000 per cubic centimeter and it would not be expecting too much to demand that no milk should be sold if it was found to contain more than this number."

The following table shows the bacteria counts from the milk produced at one of the Walker-Gordon farms during the first ten days of January while the cows were in winter conditions and during the first ten days of July while the cows were in summer conditions. The highest number of bacteria found is 3,200 while on more than half of the days the milk contained less than 1,000 bacteria per cubic centimeter.

January 1,	600
January 2,	3,200
January 3,	600
January 4,	1,200
January 5,	350
January 6,	200
January 7,	1,100
January 8,	400
January 9,	700
January 10,	1,600
July 1,	525
July 2,	1,050
July 3,	125
July 4,	2,450
July 5,	1,250
July 6,	475
July 7,	2,100
July 8,	1,350
July 9,	400
July 10,	425

Milk produced at the Briarcliff dairy farm showed the following bacterial counts for a period of three weeks:

Week ending August 28:

Herd sample,	35,000
Barn B,	3,350
Barn C,	36,500
Barn D,	8,900
Barn E,	1,750
Barn F,	3,950

Week ending September 4:

Barn B,	21,000
Barn C,	18,400
Barn D,	4,100
Barn E,	1,500
Barn F,	2,100

Week ending September 11:

Herd sample,	6,100
Barn B,	13,000
Barn C,	16,000
Barn D,	11,900
Barn E,	17,600
Barn F,	12,900

It is stated that these numbers run considerably higher than the normal because of the fact that the barns were being filled with hay thus causing considerable dust during this period. This would seem to be the case in view of the fact that a week's record during the winter showed the following results:

Herd sample,	3,150
Barn B,	950
Barn C,	300
Barn E,	1,500
Barn F,	1,200

These tests were made by the New York Medical Society after the milk reached the city.

The following week's record shows the germ content of the milk produced at Vine Hill farm:

June 20,	1,140
June 21,	4,320
June 22,	200
June 23,	2,940
June 24,	630
June 25,	2,340
June 26,	2,640

The following figures illustrate the germ content of the milk produced by the Purity Milk Co. being plated for bacteria at the time it was delivered to the consumer when from eighteen to twenty-four hours old. The figures here given represent ten consecutive counts taken at random from a year's record.

The first column represents the milk from their new improved stables while the second column shows the results obtained in ordinary old barns which were cleaned up and whitewashed and where intelligent care was used in the production and handling of the milk.

	New Barn.	Old Barn.
December 4,	200	410
December 5,	170	385
December 8,	247	463
December 10,	397	506
December 11,	150	8,565
December 14,	165	974
December 16,	460	1,237
December 19,	350	833
December 22,	447	893
December 29,	145	865
Average,	273	1,513

The comparatively low numbers of bacteria found in these "sanitary" milks at the time of delivery shows beyond a question that it is possible to supply to the consumer milk which carries a relatively low bacterial content. The question is at once forced upon us as to the cause of the great difference in numbers between "sanitary" and ordinary milk and at what point in the production or handling the greater contamination takes place. Most of the bacterial studies made of market milk have been made in the large cities after the milk has been shipped long distances and is of considerable age. Comparatively little study has been made of the germ content of ordinary milk as produced by the farmer and delivered to the local consumer or the shipping station for transportation to the larger cities. In order to improve the sanitary quality of our market milk it is necessary to know the points at which the contamination and improper care take place. Believing that it is necessary to have more data concerning the condition of the milk as it leaves the producer in order to locate the essential points of contamination this Station has for the past two years spent considerable effort in determining the actual bacterial and sanitary condition of the milk as produced and delivered by individual dairymen.

The results given in this paper were obtained from samples taken from the milk of individual producers as it was delivered to the shipping station from which it was sent to Providence, R. I.

METHOD OF THESE EXPERIMENTS.

As already stated the milk used in these experiments was obtained from the individual producers as it was delivered to the shipping station each morning. This work was made possible through the kindness and coöperation of the Providence Dairy Co. at whose plant the samples were taken. As each man's milk was received at the station his night's and morning's milk was thoroughly mixed and a sample taken. At this time the temperature of the milk was taken and also the lactometer reading which was later used for computing the total solids. A small laboratory for bacteriological work was fitted up in the building and as soon as samples were obtained they were carried to this room where plate cultures were at once made. For this work the culture media used was the milk sugar litmus gelatin which we commonly use for our milk work where a differentiation of species is desired. Three different dilutions were used for each sample of milk, duplicate plates of each dilution being made. The results given, therefore, represent the average from the six plates made. At the beginning of this work it was difficult to use dilutions which would give us the proper number of colonies per plate, but after each man's milk had been plated a few times we were able to settle upon certain dilutions for his milk which gave quite satisfactory results in each case. It was found necessary to use different dilutions for the different men inasmuch as the germ content of the milk of the different producers varied so greatly. After plating the day's samples the plates were brought to the Station laboratory for incubation. Samples of the milk were also brought to the laboratory for determining the butter-fat and the keeping quality. The latter was determined by keeping the samples under uniform conditions until they reached the laboratory when they were placed in a constant temperature of 20° C. and the time of curdling noted. From the samples brought to the laboratory notes were taken on the amount of insoluble dirt contained in the milk. Owing to the amount of work involved in making quantitative dirt

determinations it was impossible to determine the dirt by this method where so many samples were handled each day. An arbitrary scale for determining the dirt was therefore adopted. By this method each sample of milk was marked according to the dirt which was visible in the bottom of the sample bottle after it had stood a certain length of time. The scale used ran from 1 to 7. A sample containing a very slight amount of sediment was marked 1; one containing slightly more was marked 2; still more 3, and so on up the scale, 7 indicating samples containing the greatest amount of dirt. These figures, as will be seen, represent the relative amount of visible dirt which the different samples contained and are valuable simply as a means of comparison. In certain cases centrifugal tests were made to determine the amount of dirt, and in certain others the weight of the dried dirt was determined by the method described in Bulletin No. 25 of this Station, page 10. These results will be given later in connection with certain other data. It was found that the marks given on the basis of the above arbitrary scale compared very closely with the actual amounts of dirt determined by weight. It is believed, therefore, that this method gives a fairly accurate basis for comparison of the dirt which the milk contained.

After the plates had been incubated in the laboratory for six days at 20° C. they were studied and the following determinations made:

1. The total number of bacteria present.
2. The number of acid producing bacteria.
3. The number of rapid liquefying bacteria.
4. The number of slow liquefying bacteria.
5. The species or types comprising the greater part of the organisms present.

After these facts were ascertained the percentage of acid producing bacteria and the percentage of liquefiers taking the two groups together was also determined.

It will be readily understood that in order to give the results of such a line of experiments it will be necessary to use a vast number of figures. In fact it is practically impossible to present the data thus obtained in any other than in tabular form.

While certain parts of the data might be condensed into a smaller number of tables such tables would not bring out the real conditions of the milk which would be shown in the complete tables in the form that they are given in the following pages. One of the special purposes of this investigation is to show the exact condition from day to day of the milk of the different producers so far as the temperature, solids, fat, dirt, and germ content are concerned together with the nature of the bacteria present. It is manifestly impossible to bring out these facts in detail in connection with each man's milk in any other way than by giving the complete data in tabular form. In view of these facts the writer feels justified in presenting in this article the unusually large number of tables. He is, however, aware of the fact that to the average reader figures make dry reading and frequently prevent a man from reading an article which he might otherwise read; but in view of the fact that this report finds its way into the hands of scientific men who want the facts as they are, the complete tables will be given with such explanation as it seems desirable to make. In connection with each table only certain special features will be discussed while the facts which remain more or less constant throughout the series together with certain general conclusions will be left for discussion toward the end of the report.*

In all, the milk of thirty different producers was studied in this investigation and the results of the chemical and bacteriological analyses of the milk of these thirty producers are given in detail in the following pages.

PRODUCERS GROUPED ACCORDING TO GERM CONTENT OF MILK.

It was found that there was a great difference in the numbers of bacteria contained by the milk of the different men and on the basis of the total germ content it will be possible to group somewhat the results of the analyses from the different producers. This will in some measure simplify the discussion. In group I are placed all those producers whose milk contained

*In this report only the chemical and bacteriological results of the analyses will be discussed. The conditions surrounding the production and handling of the milk will be reserved for a separate discussion which will be published later. A discussion of the types and species of bacteria found in the milk of the different producers is also reserved for a separate report.

an average of less than 100,000 bacteria per cubic centimeter; group 2 contains those where the bacteria averaged between 100,000 and 500,000 per cubic centimeter; group 3 contains those producers where the bacteria averaged between 500,000 and 1,000,000 per cubic centimeter; group 4 includes the results of those men where the average is between 1,000,000 and 2,000,000 bacteria, while in group 5 are placed all those producers whose average was above 2,000,000 bacteria per cubic centimeter.

Discussion of group 1.—This group contains the results obtained from the milk of those men where the average number of bacteria per cubic centimeter is below 100,000 for the whole series of tests. The milk of but two producers comes within this group.

In Table 25 it will be seen that the lowest number of bacteria which the milk of producer No. 1 contained was 6,830 while the largest number on any day was 106,300 giving an average for the whole series of tests of 61,660 bacteria per cubic centimeter. The percentage of acid organisms varied from 10 per cent. on November 4 to 51 per cent. on December 20, the average percentage being 35.7. While the numbers of bacteria in this man's milk are the lowest of any of the thirty the insoluble dirt ran compatively high varying from 3 to 6 in the scale adopted with an average of 4.5. This relation between the dirt and the bacteria is an exception to the normal condition. It seems doubtful if milk with that amount of dirt could be held with so low a number of bacteria without the aid of preservatives. This seems especially probable inasmuch as the temperature of the milk was not below the average. The milk was not tested for preservatives and this point cannot be definitely stated. With this one exception the milk which contained relatively low numbers of bacteria showed also relatively small amounts of insoluble dirt.

In Table 26 it will be seen that the lowest number of bacteria found in the milk of producer No. 2 is 6,580 while the highest number is 663,750, the average for the whole series of tests being 81,650. The percentage of acid bacteria varied from 0 on November 1 to 86 on March 7, with an average of

TABLE 25.

Showing Composition of Milk of Producer No. 1.

DATE.	Temperature of Milk.	Specific Gravity at 60° F.	Fat.	Solids, not Fat.	Total Solids.	Relative Dirt Content.	Hours to Curdling.	Total Bacteria.	Acid Bacteria.	Per cent. Acid Bacteria.	Rapid Liquefying Bacteria.	Slow Liquefying Bacteria.	Per cent. Liquefying Bacteria.
September 23,	51	30.0	4.3	8.50	12.80	—	—	87,080	29,160	33	3,750	2,080	7
October 11,	—	30.5	3.6	8.49	12.09	5	42	166,450	73,120	44	20,620	2,500	14
November 1,	48	33.4	4.0	9.32	13.32	4	61	50,620	10,620	21	0	8,120	16
November 4,	55	34.3	4.0	9.57	13.57	3	48	94,790	9,790	10	5,410	7,910	14
December 2,	51	32.9	3.6	9.09	12.69	4	88	6,830	2,160	32	0	330	5
December 3,	50	32.7	4.0	9.12	13.12	4	71	46,500	10,080	21	0	1,830	4
December 6,	48	32.4	3.8	9.03	12.83	5	67	84,160	17,000	20	750	6,750	9
December 9,	51	31.8	4.0	8.94	12.94	3	—	27,750	6,160	22	1,410	830	8
December 20,	52	32.5	4.1	9.09	13.19	3	72	72,580	37,250	51	500	6,160	9
December 29,	49	32.5	4.0	9.07	13.07	4	—	33,000	7,580	23	166	750	3
January 3,	46	31.9	4.0	8.67	12.67	5	89	31,870	10,830	34	0	3,540	11
February 24,	42	32.0	4.5	9.04	13.54	6	—	24,910	9,910	40	0	917	4
March 3,	52	32.5	4.2	9.11	13.31	6	—	106,300	39,700	37	3,600	10,700	13
March 14,	54	33.2	4.6	9.20	13.80	6	—	30,410	13,000	46	750	500	4
Average,	**50**	**32.3**	**4.1**	**9.02**	**13.07**	**4.5**	**67**	**61,660**	**19,740**	**35.7**	**2,640**	**3,780**	**8.6**

TABLE 26.

Showing Composition of Milk of Producer No. 2.

DATE.	Temperature of Milk.	Specific Gravity at 60° F.	Fat.	Solids, not Fat.	Total Solids.	Relative Dirt Content.	Hours to Curdling.	Total Bacteria.	Acid Bacteria.	Per cent. Acid Bacteria.	Rapid Liquefying Bacteria.	Slow Liquefying Bacteria.	Per cent. Liquefying Bacteria.
September 23,	54	32.3	4.4	9.15	13.55	—	—	60,410	12,080	20	833	2,910	6
September 27,	66	31.8	—	—	—	1	24	663,750	148,750	22	10,000	17,700	4
October 11,	—	33.2	5.0	9.39	14.39	3	42	119,000	46,500	39	5,000	2,500	6
November 1,	48	34.3	5.1	9.78	14.88	2	65	8,330	0	0	0	416	5
November 11,	46	33.1	4.7	9.35	14.05	3	85	6,580	1,410	22	83	166	4
November 15,	49	34.0	5.2	9.68	14.88	2	84	33,200	18,370	55	0	625	2
December 2,	48	33.4	4.8	9.46	14.26	3	88	30,700	8,700	28	83	1,580	5
December 3,	35	33.2	5.2	9.48	14.68	3	81	15,250	3,750	25	83	208	2
December 20,	44	33.5	4.8	9.48	14.28	2	48	8,790	1,910	22	0	542	6
December 29,	44	32.2	4.7	9.13	13.83	2	—	64,700	10,330	16	1,160	30,200	48
January 3,	50	32.2	5.0	9.44	14.44	2	89	21,500	8,500	40	0	416	2
February 24,	48	33.4	5.1	9.51	14.61	1	—	18,500	14,080	76	83	1,200	7
March 7,	49	32.5	4.7	9.21	13.91	1	—	76,850	66,000	86	1,050	2,050	4
March 21,	45	33.0	4.8	9.35	14.15	1	—	15,580	4,540	29	416	1,290	11
Average,	**48**	**33.0**	**4.9**	**9.42**	**14.31**	**2**	**67**	**81,650**	**24,640**	**34.3**	**1,340**	**4,410**	**8**

34.3 per cent. The stable where this milk was produced was probably the least expensive in structure of any of the thirty barns studied, the stable being built simply as a lean-to on the end of the hay barn and constructed of cheap lumber. This stable was, however, the cleanest of the entire series. The stables were kept in good condition and the cows thoroughly groomed and clean. At milking time the udders were wiped with a dry cloth and considerable care taken to prevent dirt from falling into the milk. This fact is also clearly shown by the figures representing the dirt content as given in the table. It will be seen by these figures that the milk never went above the scale of 3 and was usually either 1 or 2. This milk averaged as clean as the milk of any of the thirty producers.

The stable of producer No. 1 is located at the side of the barn floor and is in fairly good condition. This is one of the best type of stables found. While the stable is in some respects better in arrangement than that of producer No. 2 the cows were not so well cared for and less care was taken to prevent dirt from getting into the milk. It is evident that the difference in care at milking time accounts for the difference in the amount of dirt contained in the milk of these two men.

Discussion of group 2.—All of the producers whose milk contained an average germ content greater than 100,000 and less than 500,000 per cubic centimeter are included in this group. More producers come within this group than any other, there being eleven or 36.6 per cent. of the entire number whose milk was examined. There is considerable range in the germ content of the milk of the different men which are grouped together here. The lowest average is that of producer No. 3 given in Table 27, this average being 105,800 bacteria per cubic centimeter. From this the average for the different men increases until we reach producer No. 13, Table 37, whose average for the entire series of experiments is 458,500 bacteria per cubic centimeter of milk.

TABLE 27.

Showing Composition of Milk of Producer No. 3.

DATE.	Temperature of Milk.	Specific Gravity at 60° F.	Fat.	Solids, not Fat.	Total Solids.	Relative Dirt Content.	Hours to Curdling.	Total Bacteria.	Acid Bacteria.	Per cent. Acid Bacteria.	Rapid Liquefying Bacteria.	Slow Liquefying Bacteria.	Per cent. Liquefying Bacteria.
September 16, - - - - - -	61	32.2	4.5	9.04	13.54	3	24	729,500	3,250	4	8,250	152,000	22
November 1, - - - - - -	47	30.5	5.2	8.81	14.01	2	96	18,500	250	1	0	1,250	7
November 11, - - - - - -	45	34.0	4.7	9.58	14.28	4	65	155,750	11,370	7	21,620	2,125	15
November 15, - - - - - -	45	33.5	4.0	9.32	13.32	3	93	21,790	5,160	24	292	3,790	19
November 18, - - - - - -	40	33.7	4.4	9.40	13.80	5	67	3,830	1,700	45	42	42	2
November 22, - - - - - -	47	32.8	4.4	9.27	13.67	3	72	38,000	14,160	37	0	1,500	3
December 3, - - - - - -	52	32.5	4.5	9.17	13.67	3	65	12,500	2,500	20	100	200	2
December 6, - - - - - -	48	33.4	3.8	9.28	13.08	2	67	5,620	500	9	42	625	2
December 9, - - - - - -	38	32.5	4.4	9.15	13.55	3	—	92,790	85,000	92	458	125	1
December 20, - - - - - -	48	32.0	4.2	8.98	13.18	2	96	58,870	42,200	72	83	1,125	2
February 24, - - - - - -	53	32.1	4.3	9.02	13.32	2	—	20,000	2,080	10	1,875	625	13
March 3, - - - - - -	35	30.4	4.2	8.58	12.78	2	—	88,500	48,000	54	3,500	5,000	10
March 14, - - - - - -	50	31.8	4.8	8.87	13.67	2	—	66,660	31,870	48	9,580	13,950	35
March 21, - - - - - -	45	30.9	4.1	8.69	12.79	3	—	169,160	92,700	55	833	82,290	49
Average, - - - - - -	**47**	**32.3**	**4.4**	**9.08**	**13.47**	**3**	**72**	**105,820**	**24,340**	**33.9**	**3,330**	**18,900**	**13**

TABLE 28.

Showing Composition of Milk of Producer No. 4.

DATE.	Temperature of Milk.	Specific Gravity at 60° F.	Fat.	Solids, not Fat.	Total Solids.	Relative Dirt Content.	Hours to Curdling.	Total Bacteria.	Acid Bacteria.	Per cent. Acid Bacteria.	Rapid Liquefying Bacteria.	Slow Liquefying Bacteria.	Per cent. Liquefying Bacteria.
September 16,	47	33.2	4.8	9.35	14.15	2	32	107,080	32,910	31	1,000	1,000	2
September 30,	67	26.8	6.0	8.09	14.09	—	48	391,040	244,580	62	0	1,040	.3
October 25,	53	31.2	5.5	9.04	14.54	2	39	—	—	—	—	—	—
November 1,	45	30.5	6.4	9.05	15.45	3	62	29,160	833	3	0	2,080	7
November 11,	41	33.4	4.9	9.48	14.38	3	80	4,500	1,000	22	250	200	10
November 15,	47	33.2	5.8	9.60	15.40	3	84	34,580	4,410	13	708	833	4
Average,	**50**	**31.4**	**5.6**	**9.10**	**14.67**	**2.6**	**58**	**113,270**	**56,750**	**26.2**	**390**	**1,030**	**4.7**

TABLE 29.

Showing Composition of Milk of Producer No. 5.

DATE.	Temperature of Milk.	Specific Gravity at 60° F.	Fat.	Solids, not Fat.	Total Solids.	Relative Dirt Content.	Hours to Curdling.	Total Bacteria.	Acid Bacteria.	Per cent. Acid Bacteria.	Rapid Liquefying Bacteria.	Slow Liquefying Bacteria.	Per cent. Liquefying Bacteria.
September 23, - - - - -	55	31.4	4.9	9.00	13.90	—	—	50,830	4,790	9	1,040	5,830	13
October 4, - - - - -	54	31.3	4.5	8.79	13.29	2	48	63,000	19,250	31	1,750	4,000	9
November 1, - - - - -	49	32.5	4.9	9.25	14.15	2	48	86,250	625	0.7	208	8,330	10
November 4, - - - - -	56	32.5	4.6	9.19	13.79	2	48	71,870	20,620	29	625	7,910	12
November 11, - - - - -	55	32.4	4.6	9.17	13.77	3	65	1,614,330	654,160	41	8,000	1,500	6
November 15, - - - - -	56	33.0	4.7	9.33	14.03	3	84	36,160	10,660	30	3,160	1,410	13
November 18, - - - - -	47	32.3	4.8	9.23	14.03	4	67	27,330	3,080	11	583	3,160	14
December 2, - - - - -	54	32.3	4.7	9.14	13.84	4	84	17,160	5,910	35	583	500	6
December 3, - - - - -	50	32.7	4.8	9.28	14.08	4	72	39,910	11,750	29	1,080	4,750	15
December 9, - - - - -	49	33.0	4.7	9.33	14.03	4	96	27,000	5,660	21	333	83	2
December 20, - - - - -	49	32.5	5.5	9.37	14.87	2	—	19,660	5,250	27	333	333	3
February 24, - - - - -	52	32.0	4.7	9.08	13.78	2	—	6,580	2,660	41	0	0	0
March 3, - - - - - -	51	31.9	4.6	9.05	13.65	3	—	15,000	8,250	55	500	500	7
March 14, - - - - - -	51	31.9	4.2	8.80	13.00	3	—	48,330	44,660	93	0	500	1
Average, - - - - -	**52**	**32.3**	**4.7**	**9.14**	**13.87**	**3**	**68**	**151,670**	**56,950**	**32.3**	**1,300**	**2,770**	**7.9**

TABLE 30.

Showing Composition of Milk of Producer No. 6.

DATE.	Temperature of Milk.	Specific Gravity at 60° F.	Fat.	Solids, not Fat.	Total Solids.	Relative Dirt Content.	Hours to Curdling.	Total Bacteria.	Acid Bacteria.	Per cent. Acid Bacteria.	Rapid Liquefying Bacteria.	Slow Liquefying Bacteria.	Per cent. Liquefying Bacteria.
September 23,	53	31.2	5.8	9.05	14.85	—	—	184,790	34,160	18	9,167	7,910	9
October 4,	55	30.4	5.1	8.66	13.76	3	48	46,450	11,250	24	417	2,290	6
October 25,	58	30.8	4.9	8.83	13.73	3	38	—	—	—	—	—	—
November 1,	65	31.7	5.0	9.02	14.02	4	61	115,000	10,000	9	18,330	0	16
November 11,	56	31.5	4.8	9.48	14.28	5	80	60,870	23,620	39	500	250	1
November 15,	54	32.3	5.1	9.23	14.33	5	84	60,250	17,250	28	0	625	1
November 18,	34	31.6	5.1	9.04	14.14	4	72	11,620	1,870	16	0	125	1
December 2,	54	30.8	4.8	8.80	13.60	3	72	329,100	224,100	68	2,550	9,750	4
December 3,	49	31.1	4.6	8.83	13.43	3	65	84,250	41,870	50	2,000	5,870	9
December 6,	50	29.9	4.5	8.54	13.04	3	72	47,250	10,750	23	375	1,500	4
December 29,	58	32.7	4.2	9.16	13.36	4	—	111,250	84,500	76	0	2,750	2
March 3,	59	29.9	4.9	8.60	13.50	4	—	333,250	247,000	74	2,250	12,620	4
March 21,	58	32.2	4.6	9.11	13.71	6	—	461,040	66,870	15	4,160	103,330	23
Average,	**54**	**31.2**	**4.9**	**8.95**	**13.83**	**4**	**66**	**153,760**	**64,440**	**45.9**	**3.310**	**12,250**	**6.7**

TABLE 31.

Showing Composition of Milk of Producer No. 7.

DATE.	Temperature of Milk.	Specific Gravity at 60° F.	Fat.	Solids, not Fat.	Total Solids.	Relative Dirt Content.	Hours to Curdling.	Total Bacteria.	Acid Bacteria.	Per cent. Acid Bacteria.	Rapid Liquefying Bacteria.	Slow Liquefying Bacteria.	Per cent. Liquefying Bacteria.
September 23,	55	29.4	5.2	8.56	13.76	—	—	352,700	97,910	28	625	29,580	9
October 4,	62	30.3	5.3	8.70	14.00	3	41	167,910	88,330	53	1,040	2,290	2
October 11,	—	30.8	5.5	8.95	14.45	4	33	768,950	14,370	2	2,290	61,500	8
November 1,	46	33.1	5.0	9.39	14.39	5	57	156,870	13,330	8	1,660	25,830	18
November 11,	52	32.5	6.1	9.49	15.59	6	85	73,500	25,620	35	290	583	1
November 15,	46	34.0	6.0	9.84	15.84	4	117	102,080	23,620	23	1,290	4,410	6
December 2,	40	28.1	5.0	8.16	13.16	4	84	168,330	25,000	16	2,040	17,620	12
December 29,	43	34.0	4.7	9.58	14.28	4	120	1,110,660	18,750	2	1,590	72,330	7
January 3,	53	33.1	5.0	9.41	14.41	4	108	402,000	52,410	13	3,660	5,160	2
February 24,	48	33.4	4.5	9.40	13.90	3	—	115.410	21,040	18	1,660	8,330	9
March 7,	49	33.5	4.0	9.32	13.32	5	—	71,040	60,410	85	417	1,250	2
March 14,	51	32.4	4.2	8.93	13.13	2	—	16,450	7,080	43	0	0	0
March 21,	48	33.4	3.8	9.26	13.06	—	—	99,160	32,500	33	0	10,620	11
Average,	**49**	**32.1**	**4.9**	**9.15**	**14.10**	**4**	**81**	**227,310**	**36,950**	**33.8**	**1,270**	**18,420**	**6.7**

TABLE 32.

Showing Composition of Milk of Producer No. 8.

DATE.	Temperature of Milk.	Specific Gravity at 60° F.	Fat.	Solids, not Fat.	Total Solids.	Relative Dirt Content.	Hours to Curdling.	Total Bacteria.	Acid Bacteria.	Per cent. Acid Bacteria.	Rapid Liquefying Bacteria.	Slow Liquefying Bacteria.	Per cent. Liquefying Bacteria.
September 19,	71	30.4	—	—	—	3	24	148,330	18,330	12	167	46,333	31
September 27,	66	30.8	—	—	—	2	24	1,058,540	22,700	2	2,080	28,542	3
October 25,	57	31.6	4.5	8.94	13.44	—	41	—	—	—	—	—	—
November 1,	52	33.1	4.4	9.27	13.67	3	57	87,910	417	0.4	0	8,750	10
November 4,	55	34.3	4.9	9.75	14.65	2	48	113,750	17,080	15	2,080	1,660	3
November 15,	48	32.9	4.8	9.33	14.13	3	93	24,870	3,870	16	1,000	625	7
November 22,	50	32.7	4.3	9.13	13.43	4	72	55,680	20,810	38	1,870	2,810	8
December 3,	41	32.9	4.9	9.35	14.25	6	64	281,250	67,750	24	5,370	53,875	21
December 9,	45	32.2	4.8	9.10	13.90	3	—	59,750	11,870	20	1,370	1,870	5
December 29,	41	32.9	4.4	9.25	13.65	3	—	1,708,000	446,000	26	7,120	99,750	6
February 28,	50	33.6	4.7	9.48	14.18	5	—	27,910	15,830	57	0	2,500	9
March 14,	52	32.0	4.4	8.85	13.25	4	—	64,160	28,750	45	416	3,330	6
March 21,	43	33.0	4.3	9.25	13.55	—	—	57,910	26,660	46	1,660	0	3
Average,	52	32.5	4.6	9.25	13.83	3.5	53	307,340	56,670	25.1	1,930	20,840	9.3

TABLE 33.

Showing Composition of Milk of Producer No. 9.

DATE.	Temperature of Milk.	Specific Gravity at 60° F.	Fat.	Solids, not Fat.	Total Solids.	Relative Dirt Content.	Hours to Curdling.	Total Bacteria.	Acid Bacteria.	Per cent. Acid Bacteria.	Rapid Liquefying Bacteria.	Slow Liquefying Bacteria.	Per cent. Liquefying Bacteria.
October 4,	60	28.0	4.7	8.06	12.78	3	34	147,290	18,330	12	1,450	40,620	29
October 11,	—	27.8	4.2	7.94	12.14	5	32	2,324,000	135,000	6	3,370	5,000	0.3
November 4,	59	30.9	4.3	8.75	13.05	2	48	292,910	88,120	30	8,120	29,160	13
November 11,	51	31.0	4.5	8.79	13.29	3	72	60,830	21,040	35	833	0	1
November 15,	49	29.8	5.0	8.60	13 60	3	93	12,910	4,375	34	208	416	5
November 18,	41	30.1	4.6	8.56	13 16	6	65	16,660	2,080	13	4,060	0	24
December 2,	43	29.8	4.0	8.39	12.39	3	96	19,160	6,250	33	2,080	2,290	23
December 6,	44	29.9	4.4	8.52	12.92	3	64	41,040	7,910	19	833	5,200	15
December 29,	44	31.2	4.6	8.86	13.46	2	—	165,500	45,500	27	1,000	6,500	5
January 3,	55	29.9	4.7	8.55	13 25	2	86	294,160	137,500	47	8,750	27,910	12
February 24,	54	31.3	4.9	8.94	13.84	3	—	1,295,210	878,540	68	13,750	23,700	3
March 3,	47	30.5	4.2	8.61	12.81	4	—	190,410	60,830	32	4,370	4,580	5
March 14,	49	28.9	4.7	8.12	12.82	3	—	143,330	40,830	29	0	412	0.3
March 21,	48	29.7	4.6	8.49	13.09	3	—	272,500	115,000	42	1,870	5,000	3
Average,	**50**	**29.9**	**4.5**	**8.54**	**13.04**	**3**	**68**	**376,850**	**111,520**	**30.5**	**3,620**	**10,770**	**9.9**

TABLE 34.

Showing Composition of Milk of Producer No. 10.

DATE.	Temperature of Milk.	Specific Gravity at 60° F.	Fat.	Solids, not Fat.	Total Solids.	Relative Dirt Content.	Hours to Curdling.	Total Bacteria.	Acid Bacteria.	Per cent. Acid Bacteria.	Rapid Liquefying Bacteria.	Slow Liquefying Bacteria.	Per cent. Liquefying Bacteria.
September 23,	51	32.9	3.9	9.17	13.07	—	—	53,330	6,040	11	1,042	3,330	8
October 4,	54	34.2	4.3	9.50	13.80	2	48	35,410	11,870	31	833	2,910	11
October 25,	51	29.1	4.2	8.25	12.45	2	48	—	—	—	—	—	—
November 1,	45	33.1	4.1	9.21	13.31	2	65	25,830	3,540	14	1,250	1,660	11
November 11,	52	33.0	4.8	9.35	14.15	3	83	653,330	2,290	0.3	0	167	0
November 15,	54	35.2	5.0	9.81	14.81	3	84	4,055,000	1,250	0	0	0	0
November 18,	47	34.1	5.2	9.68	14.88	3	67	2,500	458	18	708	375	43
December 2,	45	30.4	5.0	9.48	14.48	3	84	1,330	0	0	42	0	3
December 6,	41	33.8	5.2	9.68	14.88	3	84	10,830	1,410	13	500	542	10
December 9,	45	32.6	5.7	9.41	15.11	2	—	2,000	875	44	0	42	2
December 29,	42	32.9	4.7	9.30	14.00	1	—	130,290	458	0.4	0	127,200	98
February 28,	61	32.2	5.5	9.29	14.79	3	—	20,500	6,750	33	83	1,750	9
March 7,	48	32.4	4.5	9.14	13.64	2	—	63,560	21,310	33	2,250	6,870	14
Average,	**49**	**32.8**	**4.8**	**9.33**	**14.11**	**2.4**	**70**	**421,160**	**4,690**	**16.5**	**560**	**12,070**	**18.4**

TABLE 35.

Showing Composition of Milk of Producer No. 11.

DATE.	Temperature of Milk.	Specific Gravity at 60° F.	Fat.	Solids, not Fat.	Total Solids.	Relative Dirt Content.	Hours to Curdling.	Total Bacteria.	Acid Bacteria.	Per cent. Acid Bacteria.	Rapid Liquefying Bacteria.	Slow Liquefying Bacteria.	Per cent. Liquefying Bacteria.
September 23, - - - -	57	29.7	4.5	8.54	13.04	—	—	152,910	55,410	36	2,080	11,870	9
September 30, - - - -	67	30.9	4.5	8.79	13.29	—	42	1,962,080	822,000	42	5,410	13,330	1
October 28, - - - -	38	33.0	4.0	9.19	13.19	3	63	77,080	14,160	18	5,410	1,250	9
November 4, - - - -	54	32.3	4.4	9.15	13.55	3	48	163,120	21,040	13	1,660	51,450	33
November 11, - - - -	49	30.7	5.6	8.93	14.53	6	83	29,410	6,000	20	167	250	1
November 18, - - - -	37	31.5	4.2	8.86	13.06	5	57	217,660	92,330	42	2,330	17,160	9
November 22, - - - -	45	32.6	3.7	9.01	12.71	4	72	161,330	72,580	45	917	5,750	4
December 3, - - - -	40	31.2	4.0	8.74	12.74	4	65	97,250	30,750	32	1,660	11,080	13
December 9, - - - -	46	31.4	4.0	8.82	12.82	4	—	69,250	43,500	63	333	833	2
December 20, - - - -	50	32.7	4.4	9.18	13.58	4	72	133,250	22,250	17	83	13,000	10
February 28, - - - -	50	31.8	4.4	8.98	13.38	4	—	86,080	51,830	60	666	3,330	5
March 7, - - - - -	44	33.0	4.3	9.25	13.55	3	—	18,080	8,910	50	83	1,166	7
March 21, - - - - -	48	32.4	5.2	9.29	14.49	7	—	2,374,160	1,135,830	48	3,000	107,830	5
Average, - - - -	**48**	**31.8**	**4.4**	**8.90**	**13.38**	**4**	**63**	**426,280**	182,810	**53.5**	**1,830**	**18,330**	**8.3**

TABLE 36.

Showing Composition of Milk of Producer No. 12.

DATE.	Temperature of Milk.	Specific Gravity at 60° F.	Fat.	Solids, not Fat.	Total Solids.	Relative Dirt Content.	Hours to Curdling.	Total Bacteria.	Acid Bacteria.	Per cent. Acid Bacteria.	Rapid Liquefying Bacteria.	Slow Liquefying Bacteria.	Per cent. Liquefying Bacteria.
September 23, - - - - -	56	32.5	4.9	9.25	14.15	—	—	180,000	45,620	25	5,620	7,500	7
September 27, - - - - -	68	32.2	—	—	—	6	24	925,000	280,000	30	280,000	10,830	31
October 28, - - - - - -	49	27.5	5.4	8.09	13.49	4	96	316,660	16,660	5	0	16,660	5
Average, - - - - - -	**58**	**3.07**	**5.2**	**8.67**	**13.82**	**5**	**60**	**473,890**	**114,090**	**20.0**	**95,200**	11,660	**14.3**

TABLE 37.

Showing Composition of Milk of Producer No. 13.

DATE.	Temperature of Milk.	Specific Gravity at 60° F.	Fat.	Solids, not Fat.	Total Solids.	Relative Dirt Content.	Hours to Curdling.	Total Bacteria.	Acid Bacteria.	Per cent. Acid Bacteria.	Rapid Liquefying Bacteria.	Slow Liquefying Bacteria.	Per cent. Liquefying Bacteria.
September 19, - - - - -	70	30.3	—	—	—	3	24	1,567,000	559,660	36	5,080	24,250	2
October 4, - - - - -	55	31.4	5.5	8.99	14.49	3	48	102,000	24,160	23	10,000	8,330	18
October 11, - - - - -	—	—	4.6	8.35	—	4	42	2,370,000	1,213,700	51	35,410	26,250	3
October 28, - - - - -	38	29.0	4.8	—	13.15	4	48	630,830	231,660	37	14,160	9,160	4
November 4, - - - - -	51	28.1	4.5	8.04	12.54	3	63	79,160	5,830	7	0	1,660	2
November 11, - - - - -	44	31.2	4.2	8.77	12.97	3	63	69,580	28,330	41	417	2,500	4
November 15, - - - - -	46	30.5	4.5	8.67	13.17	4	64	147,700	61,450	42	9,580	10,410	14
December 3, - - - - -	47	30.0	4.1	8.46	12.56	3	65	62,700	4,160	7	2,910	3,750	11
December 9, - - - - -	43	30.2	3.8	8.40	12.20	3	87	8,750	1,450	17	625	416	12
December 20, - - - - -	52	27.2	3.6	7.64	11.24	3	—	123,330	41,870	34	2,290	5,620	19
February 24, - - - - -	51	31.9	4.3	8.98	13.28	4	—	114,370	37,370	33	250	2,250	2
March 3, - - - - -	44	32.2	4.5	9.09	13.59	4	—	614,660	261,330	43	25,660	13,330	6
March 14, - - - - -	47	31.4	4.6	8.74	13.34	5	—	458,500	243,370	53	15,500	9,500	5
Average, - - - - -	**49**	**30.3**	**4.4**	**8.56**	**12.96**	**3.5**	**56**	**488,430**	**208,800**	**32.6**	**9,370**	**9,030**	**8.0**

As would be expected the number of bacteria found in the milk of the different producers varies considerably from day to day as a result of variation in the conditions of cleanliness in obtaining and handling the milk for any given day. A study of Tables 27 to 37, however, shows that the increase in the average for each man is caused by a fairly constant increase in the numbers in the several experiments. In other words, those men whose milk shows the higher average for the entire series also shows the higher number in the majority of the daily tests. While this is true in general there are a few exceptions. For example, in Table 29 the number of bacteria normally found in the milk is no greater than the numbers found in Table 27, the greater average in this case being due to the extremely high germ content of the milk on November 11. In most cases, however, the average represents the normal condition of the milk of each producer.

Acid Producing Bacteria.—A study of the acid organisms in this group of tables shows that there is perhaps, even a greater variation in the numbers of acid bacteria from day to day than there is in the total numbers of bacteria. The number of acid bacteria found in any sample of milk seems to bear no direct relation to the total number of bacteria which the milk contained. This is shown both in the daily tests for the different producers and also in the average of the acid bacteria for the entire series of samples from each man. Not only do the actual numbers of acid bacteria vary greatly from day to day but the percentages also vary between wide limits, not infrequently there being less than 1 per cent. of acid bacteria while the same man's milk may on another day contain over 90 per cent. regardless of the total number of bacteria found in the milk. There seems to be no constant relation between the per cent. of acid bacteria and the total number of organisms contained in the different samples. It has already been brought out in a previous publication by this Station that the keeping quality of milk is not wholly dependent either upon the total number of bacteria or the percentage of acid organisms which it contains. The species of organisms is of greater importance than the actual number from the standpoint of its keeping qualities. The same condition is shown very strikingly in these tables

but while the percentage of acid organisms bears no close relation to the length of time which the milk will keep there does exist a fairly uniform relation between the percentage of acid bacteria and the amount of dirt which the milk contains. A study of these tables reveals the fact that a high dirt content normally goes with a high percentage of acid bacteria while a low dirt content is commonly accompanied by a low percentage of acid organisms. While this relation is not always uniform and while many exceptions may be found, this seems to be a moral condition. This condition is what would naturally be expected since the acid organisms which commonly sour milk are introduced from external sources with the dirt and dust which gain access to the milk. It is very natural, therefore, that a fairly uniform relation should exist between the amount of dirt and the percentage of acid organisms contained in the milk. It must be borne in mind that a portion of the dirt contamination of the milk had gone into solution and does not appear in the figures representing the relative dirt content in these tables. It is probable that the relation between the dirt content and the percentage of acid organisms would be more uniform if the actual total dirt contamination were determined. While it is not the purpose of this article to discuss the conditions under which the milk was produced, it may be said here that the stable conditions bear a fairly direct relation to the amount of dirt and the numbers of bacteria found in the milk of the different producers. The construction of some of the stables is fairly good and with more care in the management a much better quality of milk might be produced. A few of the stables in this group were of rather bad construction for the purpose of producing a good grade of milk.

Discussion of group 3.— This group contains the milk from those farms where the germ content for the entire series of tests was between 500,000 and 1,000,000 bacteria per cubic centimeter. The milk of but two producers comes in this group. The principal difference between the milk given in these tables and that given in the preceding group of tables lies in the greater germ content. It will be seen in Table 38 in the column marked "Total bacteria" that the variation from day to day is very marked. The lowest number which

TABLE 38.

Showing Composition of Milk of Producer No. 14.

Date.	Temperature of Milk.	Specific Gravity at 60° F.	Fat.	Solids, not Fat.	Total Solids.	Relative Dirt Content.	Hours to Curdling.	Total Bacteria.	Acid Bacteria.	Per cent. Acid Bacteria.	Rapid Liquefying Bacteria.	Slow Liquefying Bacteria.	Per cent. Liquefying Bacteria.
September 16,	57	31.6	5.0	8.77	13.77	2	32	2,831,660	2,828,000	99	2,080	1,580	0.1
October 4,	53	33.1	4.4	9.27	13.67	2	48	130,830	35,000	27	8,330	15,000	18
October 28,	42	35.8	3.9	9.87	13.77	2	63	52,080	21,250	41	0	5,000	10
November 4,	52	33.9	4.7	9.58	14.28	2	48	67,080	15,500	23	0	7,080	11
November 11,	47	33.2	5.0	9.43	14.43	2	88	53,750	8,500	16	0	750	1
November 15,	51	33.8	4.9	9.56	14.46	4	84	137,500	117,750	86	750	2,125	2
November 18,	38	34.5	4.3	9.63	13.93	4	62	27,120	19,625	73	0	250	1
December 2,	53	33.5	4.8	9.48	14.28	3	84	26,870	12,250	45	500	2,000	9
December 20,	50	33.6	4.7	9.49	14.19	5	82	156,370	51,375	33	1,500	625	1
December 29,	49	34.0	4.8	9.60	14.40	5	—	137,870	56,375	41	0	375	0.3
February 28,	54	33.2	4.7	9.12	13.82	4	—	1,682,500	1,641,660	98	1,660	2,080	0.2
March 7,	45	33.0	4.2	9.23	13.43	4	—	158,330	136,040	86	1,250	4,790	4
March 21,	46	32.3	4.3	9.08	13.38	5	—	1,800,000	1,629,790	91	7,700	6,040	1
Average,	**48**	**33.5**	**4.6**	**9.38**	**13.98**	**3.4**	**66**	**558,610**	**505.620**	**58.4**	**1,830**	**3,670**	**4.5**

TABLE 39.

Showing Composition of Milk of Producer No. 15.

Date.	Temperature of Milk.	Specific Gravity at 60° F.	Fat.	Solids, not Fat.	Total Solids.	Relative Dirt Content.	Hours to Curdling.	Total Bacteria.	Acid Bacteria.	Per cent. Acid Bacteria.	Rapid Liquefying Bacteria.	Slow Liquefying Bacteria.	Per cent. Liquefying Bacteria.
September 23, - - - -	54	30.3	4.9	8.75	13.65	—	—	65,500	7,500	11	250	6,250	10
September 30, - - - -	64	30.5	4.7	8.71	13.41	—	35	2,730,830	1,117,000	41	35,750	42,500	29
October 28, - - - -	50	30.9	5.5	8.94	14.44	3	56	99,580	17,080	17	1,660	0	2
November 4, - - - -	53	32.1	5.5	9.27	14.74	4	63	137,910	18,950	14	208	12,700	9
November 11, - - - -	59	30.9	5.4	8.95	14.35	5	85	49,250	3,625	7	2,250	1,500	8
Average, - - - -	**56**	**30.9**	**5.2**	**8.92**	**14.12**	**4**	**60**	**616,610**	**232,930**	**18.0**	**8,025**	**12,590**	**11.6**

the milk contained on any day is 26,870 on December 2d. From this relatively low number the germ content runs up to 2,831,000 on September 16. This is a higher number than was found in any of the samples in either group 1 or 2. The percentage of acid organisms is also higher in this case than any of those discussed up to this point. The variation in the percentage of acid organisms runs from 16 up to 99 while the average for the entire series of experiments is 58.4 per cent. This increase in the proportion of acid organisms indicates that the milk was either quite old or else had been kept at such warm temperatures that the bacteria had multiplied with great rapidity by the time the milk was delivered. In fact the milk of this producer was not infrequently sour when delivered and was rejected by the shippers. Producer No. 15 stopped sending his milk to the shipping station after a few samples had been obtained. The figures given in Table 39 present no striking features worthy of discussion at this point. The average germ content of his milk places it in this group. The dirt content is rather high, the average percentage of acid organisms is lower than for many of the other men. As already stated the chief difference in regard to these two producers is the somewhat greater germ content than is found in the preceding groups.

Discussion of group 4.—In this group are placed the results obtained from the milk which showed an average number of bacteria between 1,000,000 and 2,000,000 per cubic centimeter. The milk of seven men comes within these limits. This is 23.3 per cent. of the entire number of producers whose milk was being studied. The milk of these men was delivered at the shipping station at the same time as that contained in the preceding groups. The increased germ content must, therefore, be due to some other cause than the greater age of the milk. This cause is manifestly the difference in conditions under which the milk was produced and handled. A study of the total numbers as given in the different tables in this group shows a large variation from day to day and in some cases the germ content was relatively very low, being as low as 6,169 on November 18, Table 40. On December 20 the milk of the same man showed a germ content of considerably

TABLE 40.

Showing Composition of Milk of Producer No. 16.

DATE.	Temperature of Milk.	Specific Gravity at 60° F.	Fat.	Solids, not Fat.	Total Solids.	Relative Dirt Content.	Hours to Curdling.	Total Bacteria.	Acid Bacteria.	Per cent. Acid Bacteria.	Rapid Liquefying Bacteria.	Slow Liquefying Bacteria.	Per cent. Liquefying Bacteria.
September 23,	49	30.7	5.2	8.93	14.13	—	—	91,000	18,000	20	3,500	7,500	12
September 30,	67	30.9	4.3	8.75	13.05	—	37	3,541,000	1,770,000	50	4,790	11,450	0.4
October 11,	—	31.8	4.6	9.02	13.62	5	40	582,290	2,500	0.4	7,080	6,870	2
November 1,	50	34.5	3.9	9.54	13.44	3	59	66,870	5,310	8	0	2,500	4
November 18,	42	32.5	4.3	9.13	13.43	5	71	6,160	1,080	18	0	417	7
November 22,	42	34.4	4.2	9.60	13.80	4	90	77,870	11,120	81	625	3,000	5
December 2,	45	32.6	4.0	9.10	13.10	3	96	63,160	6,580	10	0	1,250	2
December 3,	39	32.6	4.2	9.13	13.33	3	72	160,250	57,750	36	250	14,250	9
December 20,	48	32.9	4.7	9.30	14.00	2	56	9,269,000	8,630,000	93	5,250	91,750	1
December 29,	46	31.9	3.8	9.08	12.88	2	38	817,910	666,250	81	416	7,080	1
January 3,	43	32.6	4.4	9.17	13.57	2	86	134,160	27,580	21	1,250	9,660	8
February 24,	44	33.0	4.5	9.29	13.79	3	—	30,000	20,200	67	0	1,250	4
March 14,	41	33.8	4.5	9.33	13.83	2	—	111,750	11,000	10	0	3,250	3
March 21,	37	32.4	4.4	9.13	13.53	3	—	58,330	9,790	17	0	625	1
Average,	**46**	**32.6**	**4.4**	**9.14**	**13.54**	**3**	**65**	**1,072,000**	**802,650**	**36.6**	**1,650**	**11,490**	**4.2**

TABLE 41.

Showing Composition of Milk of Producer No. 17.

Date.	Temperature of Milk.	Specific Gravity at 60° F.	Fat.	Solids, not Fat.	Total Solids.	Relative Dirt Content.	Hours to Curdling.	Total Bacteria.	Acid Bacteria.	Per cent. Acid Bacteria.	Rapid Liquefying Bacteria.	Slow Liquefying Bacteria.	Per cent. Liquefying Bacteria.
September 23,	52	34.9	4.9	9.87	14.77	—	—	428,750	133,750	31	3,540	6,450	2
September 30,	68	31.1	5.6	9.01	14.61	—	34	10,352,000	9,150,000	89	2,910	33,540	0.4
October 11,	—	32.9	6.5	9.75	16.25	5	33	3,317,000	614,160	18	11,250	15,410	1
November 1,	48	35.5	6.5	10.17	16.67	3	72	88,000	13,000	15	0	2,000	2
November 18,	40	35.2	5.9	10.07	15.97	3	65	24,370	8,750	36	208	1,660	8
November 22,	38	34.5	5.1	9.78	14.88	3	87	60,200	16,040	27	1,870	2,500	7
December 2,	37	33.4	5.8	9.65	15.45	3	89	48,330	13,120	27	0	3,950	8
December 6,	39	34.1	5.0	9.64	14.64	3	72	249,370	25,410	10	625	17,910	7
December 20,	48	33.4	5.8	9.64	15.44	2	96	206,750	142,000	69	1,000	4,250	3
December 29,	43	35.0	5.2	9.80	15.00	3	36	558,950	187,290	34	9,580	81,250	16
January 3,	47	34.1	4.7	9.60	14.30	3	89	221,040	38,330	17	9,580	10,410	9
February 24,	48	32.4	5.1	9.27	14.37	2	—	95,500	57,500	60	1,000	18,000	20
March 3,	45	32.2	5.0	9.19	14.19	2	—	147,080	91,660	62	4,580	7,080	8
March 14,	47	32.3	4.7	8.99	13.69	3	—	349,580	169,160	48	416	17,910	5
Average,	**46**	**33.6**	**5.4**	**9.62**	**15.02**	**3**	**67**	**1,153,000**	**761,440**	**38.8**	**3,320**	**15,880**	**6.9**

TABLE 42.

Showing Composition of Milk of Producer No. 18.

DATE.	Temperature of Milk.	Specific Gravity at 60° F.	Fat.	Solids, not Fat.	Total Solids.	Relative Dirt Content.	Hours to Curdling.	Total Bacteria.	Acid Bacteria.	Per cent. Acid Bacteria.	Rapid Liquefying Bacteria.	Slow Liquefying Bacteria.	Per cent. Liquefying Bacteria.
September 20, - - - - -	54	31.3	5.0	8.77	13.77	—	—	273,330	36,450	13	1,040	5,410	2
September 27, - - - - -	57	30.6	—	—	—	2	48	109,970	70,000	64	0	208	2
October 11, - - - - -	—	—	4.7	—	—	5	66	2,495,000	788,000	32	14,750	15,000	1
October 28, - - - - -	41	32.9	5.1	9.36	14.46	4	63	28,330	3,330	12	0	0	0
November 1, - - - - -	47	33.2	5.2	9.43	14.63	3	62	50,830	417	0.8	0	417	1
November 18, - - - - -	42	32.5	5.0	9.27	14.27	4	70	49,250	18,870	39	2,250	1,000	7
November 22, - - - - -	53	33.1	5.4	9.47	14.87	4	87	58,650	6,300	11	1,500	1,800	6
December 2, - - - - -	44	33.0	4.1	9.21	13.31	4	90	25,120	5,870	23	125	1,370	6
December 6, - - - - -	49	33.5	4.5	9.42	13.92	2	67	30,000	7,120	24	250	625	3
December 9, - - - - -	51	31.9	4.7	9.08	13.78	2	—	60,870	3,000	5	3,250	2,875	10
January 3, - - - - -	43	32.6	4.2	9.13	13.33	2	65	5,904,000	5,810,000	98	2,620	31,000	0.6
February 24, - - - - -	45	32.2	4.4	9.19	13.59	3	—	31,250	9,160	30	0	830	3
March 7, - - - - -	44	33.2	4.6	9.11	13.71	3	—	9,100,000	9,087,000	99	417	3,750	0
March 21, - - - - -	43	33.0	4.6	9.31	13.91	3	—	37,910	15,410	41	0	1,660	4
Average, - - - -	**47**	**32.5**	**4.7**	**9.18**	**13.88**	**3**	**69**	**1,303,000**	**1,133,000**	**35.1**	**1,870**	**4,710**	**3.3**

TABLE 43.

Showing Composition of Milk of Producer No. 19.

DATE.	Temperature of Milk.	Specific Gravity at 60° F.	Fat.	Solids, not Fat.	Total Solids.	Relative Dirt Content.	Hours to Curdling.	Total Bacteria.	Acid Bacteria.	Per cent. Acid Bacteria.	Rapid Liquefying Bacteria.	Slow Liquefying Bacteria.	Per cent. Liquefying Bacteria.
September 19,	65	29.6	—	—	—	6	24	1,004,000	58,660	6	7,000	23,250	3
September 27,	63	30.4	—	—	—	4	24	3,384,000	1,505,000	44	3,750	31,250	1
September 30,	65	30.7	4.6	8.69	13.29	—	34	4,320,000	527,500	12	14,250	11,000	6
October 4,	52	32.0	4.1	8.96	13.06	2	48	6,076,000	4,998,000	82	29,160	119,160	2
October 28,	43	32.1	4.0	8.96	12.96	4	63	488,580	108,330	22	12,500	20,830	7
November 4,	58	32.7	4.4	9.15	13.55	3	48	312,500	44,160	11	830	117,500	57
November 22,	43	32.4	4.2	9.11	13.31	6	87	560,410	426,250	76	0	0	0
December 3,	39	30.7	4.3	8.68	12.98	6	72	102,910	65,830	64	0	0	0
December 6,	38	32.0	4.3	9.00	13.30	6	84	364,580	300,830	83	417	2,910	1
December 29,	49	32.5	4.4	9.15	13.55	6	—	116,250	33,750	29	830	1,660	2
February 24,	51	31.0	4.6	8.81	13.41	6	—	1,335,000	1,280,000	96	3,330	0	0.2
March 3,	48	31.5	4.5	8.92	13.42	6	—	33,330	12,500	37	0	5,000	15
March 14,	55	30.4	4.6	8.49	13.09	7	—	85,830	17,500	20	3,330	8,330	15
March 21,	47	31.9	4.2	8.96	13.16	7	—	64,160	12,500	20	3,330	0	4
Average,	**51**	**31.4**	**4.4**	**8.86**	**13.26**	**5**	**54**	**1,303,000**	**670,850**	**41.0**	**5,625**	**28,630**	**8.0**

TABLE 44.

Showing Composition of Milk of Producer No. 20.

DATE.	Temperature of Milk.	Specific Gravity at 60° F.	Fat.	Solids, not Fat.	Total Solids.	Relative Dirt Content.	Hours to Curdling.	Total Bacteria.	Acid Bacteria.	Per cent. Acid Bacteria.	Rapid Liquefying Bacteria.	Slow Liquefying Bacteria.	Per cent. Liquefying Bacteria.
September 16, - - -	59	31.5	4.0	8.57	12.57	2	44	5,573,000	1,202,000	22	5,500	6,250	0.2
September 30, - - -	70	30.3	4.9	8.75	13.65	—	45	3,083,000	722,080	23	1,875	4,160	0.2
October 4, - - - -	56	30.5	5.1	8.66	13.76	3	48	591,660	229,160	39	18,750	25,000	7
October 11, - - -	—	32.3	5.3	9.28	14.58	3	41	11,603,000	8,660,000	75	20,000	41,660	1
November 1, - - -	49	34.4	5.0	9.76	14.76	3	62	45,000	5,830	13	5,000	1,660	15
November 22, - - -	47	32.3	5.6	9.39	14.99	3	86	107,060	21,000	20	5,060	8,430	13
December 3, - - -	44	32.6	5.7	9.43	15.13	4	70	91,500	13,000	14	1,125	5,125	7
December 6, - - -	46	33.1	5.2	9.43	14.63	4	64	522,500	55,000	11	13,330	30,000	8
December 9, - - -	41	34.3	4.7	9.71	14.41	2	—	20,875	4,500	22	0	500	2
December 20, - - -	44	33.5	4.7	9.46	14.16	1	82	76,750	10,250	13	125	2,125	3
January 3, - - - -	45	32.2	4.5	9.09	13.59	2	104	95,000	26,450	28	2,080	5,410	8
February 28, - - -	43	32.1	5.0	9.16	14.16	2	—	800,375	778,250	97	250	1,875	0.3
March 7, - - - -	45	33.0	4.9	9.37	14.27	1	—	37,500	25,250	67	0	4,625	12
March 21, - - - -	41	33.4	5.0	9.49	14.49	2	—	59,000	14,120	24	625	2,750	6
Average, - - -	**48**	**32.5**	**5.0**	**9.22**	**14.22**	**2.4**	**65**	**1,621,000**	**840,530**	**33.5**	**5,260**	**9,970**	**5.9**

TABLE 45.

Showing Composition of Milk of Producer No. 21.

Date.	Temperature of Milk.	Specific Gravity at 60° F.	Fat.	Solids, not Fat.	Total Solids.	Relative Dirt Content.	Hours to Curdling.	Total Bacteria.	Acid Bacteria.	Per cent. Acid Bacteria.	Rapid Liquefying Bacteria.	Slow Liquefying Bacteria.	Per cent. Liquefying Bacteria.
September 16, - - - - -	57	30.6	3.6	8.49	12.09	3	36	197,950	37,125	19	875	3,290	2
September 27, - - - - -	64	30.5	—	—	—	2	24	382,080	126,040	33	416	7,290	2
September 30, - - - - -	69	30.2	4.0	8.44	12.44	—	32	7,940,000	52,810	0.6	3,250	65,250	1
October 11, - - - - -	—	32.5	4.0	9.07	13.07	4	38	1,446,000	1,115,000	77	21,000	21,000	2
November 1, - - - - -	51	33.8	3.8	9.40	13.20	4	59	24,000	250	1	1,000	1,500	10
November 22, - - - - -	46	33.1	3.1	9.01	12.11	6	72	1,260,000	1,207,000	96	3,650	2,250	0.5
December 2, - - - - -	42	32.0	3.2	8.78	11.98	6	72	5,756,000	5,753,000	99	250	790	0
December 6, - - - - -	48	32.9	2.9	8.98	11.88	6	67	190,250	31,660	17	2,950	2,910	3
December 9, - - - - -	37	33.9	2.6	8.16	11.76	6	—	38,700	6,625	17	625	1,410	5
December 20, - - - - -	34	32.5	3.9	9.05	12.95	7	96	76,700	20,330	27	166	2,375	3
March 21, - - - - - -	43	31.1	3.8	8.67	12.47	7	—	1,318,000	1,165,000	88	8,950	18,330	2
Average, - - - - -	**49**	**32.1**	**3.5**	**8.90**	**12.40**	**5**	**55**	**1,693,000**	**865,100**	**43.1**	**3,920**	**9,900**	**2.8**

TABLE 46.

Showing Composition of Milk of Producer No. 22.

DATE.	Temperature of Milk.	Specific Gravity at 60° F.	Fat.	Solids, not Fat.	Total Solids.	Relative Dirt Content.	Hours to Curdling.	Total Bacteria.	Acid Bacteria.	Per cent. Acid Bacteria.	Rapid Liquefying Bacteria.	Slow Liquefying Bacteria.	Per cent. Liquefying Bacteria.
September 16, - - -	59	31.0	3.9	8.67	12.57	2	44	97,580	18,000	18	1,410	10,410	12
September 27, - - -	66	30.8	—	—	—	2	24	10,606,000	10,606,000	99	2,080	28,330	0.3
October 28, - - -	42	31.0	4.6	8.81	13.41	2	48	689,160	398,330	58	7,500	6,660	2
November 4, - - -	54	31.3	4.2	8.86	13.06	2	48	3,452,000	2,651,000	77	11,250	28,330	1
November 18, - - -	42	31.0	4.8	8.85	13.65	3	57	748,330	235,000	31	8,330	5,000	2
November 22, - - -	44	31.7	4.4	8.90	13.30	4	72	352,500	70,000	20	7,500	25,000	9
December 2, - - -	51	30.5	4.5	8.67	13.17	2	84	1,118,000	314,000	28	219,000	97,000	28
December 6, - - -	42	32.0	4.8	9.10	13.90	2	67	183,330	60,000	33	1,660	5,830	4
December 20, - - -	49	32.5	4.5	9.17	13.67	2	109	545,000	64,160	12	11,660	92,500	19
January 3, - - -	45	30.4	4.2	8.59	12.79	2	64	1,600,000	1,135,000	71	23,330	6,660	2
February 28, - - -	40	31.7	4.5	8.97	13.47	1	—	21,660	5,830	27	2,080	833	14
March 7, - - - -	44	31.2	4.2	8.78	12.98	3	—	2,515,000	2,306,000	92	14,500	39,000	2
March 21, - - - -	44	31.2	4.5	8.84	13.34	1	—	1,130,000	1,032,000	91	833	179,580	16
Average, - - -	**49**	**31.3**	**4.4**	**8.88**	**13.28**	**2**	**62**	**1,773,000**	**1,453,000**	**50.5**	**16,240**	**40,390**	**8.5**

over 9,000,000 bacteria per cubic centimeter. In the majority of tests as shown in this group of tables the germ content averages materially higher than was found in the earlier groups and the average given in connection with each table represents fairly well the general bacterial condition of the milk of the given producer. The average percentage of acid organisms in this group is considerably higher than was found in the preceding groups. This indicates that at least a portion of the increase in total germ content is due to the rapid development of the acid bacteria in the milk. The dirt content of some of the samples is rather high while on the other hand some of the samples were among the cleanest ones found, the average for the group being practically the same as for group 2. It is evident from this that the increase in bacteria is not due in this case to a greater dirt contamination and must, therefore, be attributed to the rapid development of the acid bacteria.

Discussion of group 5.—This group includes the milk from those farms where the average germ content was above 2,000,000 bacteria per cubic centimeter, the milk from eight farms exceeded this number and is therefore included in this group. This is 26.6 per cent. of the whole number of farms from which milk was studied. The smallest average number of bacteria for the milk of any of the men included in this group is 2,745,000 as shown in Table 47. The lowest test for this man is 220,000 on March 23, while his highest test occurred on January 1, when his milk contained 19,920,000 bacteria per cubic centimeter. The milk of producer No. 30 has the highest average bacterial content. The results obtained from his milk are given in Table 54, where the average is shown to be 19,174,000. The germ content of this milk did not fall below 1,000,000 in any test and the highest point was reached on October 11, when the milk contained the enormous number of over 88,000,000 bacteria per cubic centimeter. This is the highest number found in any of the tests.

The high percentage of acid producing bacteria found in the milk of this group is very noticeable, it being much higher in this group than in any of the preceding groups. In individual experiments the acid producing organisms not infrequently constitute as high as 99 per cent. of all the organisms present in the milk.

TABLE 47.

Showing Composition of Milk of Producer No. 23.

DATE.	Temperature of Milk.	Specific Gravity at 60° F.	Fat.	Solids, not Fat.	Total Solids.	Relative Dirt Content.	Hours to Curdling.	Total Bacteria.	Acid Bacteria.	Per cent. Acid Bacteria.	Rapid Liquefying Bacteria.	Slow Liquefying Bacteria.	Per cent. Liquefying Bacteria.
September 23, - - -	56	31.5	4.8	8.98	13.78	—	—	296,660	185,000	62	830	5,000	2
October 4, - - -	58	31.7	4.7	9.08	13.78	2	40	1,814,000	431,660	24	6,450	16,660	1
October 25, - - -	56	31.5	5.2	9.06	14.26	2	38	—	—	—	—	—	—
October 28, - - -	47	33.2	4.5	9.34	13.84	2	48	205,000	23,330	11	5,000	13,330	9
November 11, - - -	38	32.5	4.1	9.09	13.19	5	80	251,450	83,540	33	5,620	3,540	4
November 15, - - -	46	32.3	4.8	9.18	13.98	5	84	236,040	42,910	18	10,000	9,580	8
November 22, - - -	42	33.4	4.4	9.40	13.80	5	68	3,438,000	3,285,000	96	8,000	11,250	1
December 3, - - -	35	32.2	4.1	9.00	13.10	3	72	566,250	103,750	18	6,660	112,700	21
December 9, - - -	36	30.5	4.5	9.42	13.92	3	—	1,091,000	395,000	36	40,625	67,700	10
January 3, - - -	46	33.1	4.0	9.22	13.22	3	80	13,920,000	13,903,000	99	1,070	10,200	0.1
February 28, - - -	49	32.5	4.7	9.21	13.91	5	—	8,163,000	8,111,000	99	6,660	33,330	0.5
March 7, - - -	37	32.4	3.3	8.90	12.20	3	—	220,000	68,330	31	0	1,660	1
Average, - - -	**46**	**32.2**	**4.4**	**9.18**	**13.58**	**3.5**	**64**	**2,745,000**	**2,421,000**	**48.0**	**8,260**	**25,900**	**5.2**

TABLE 48.

Showing Composition of Milk of Producer No. 24.

Date.	Temperature of Milk.	Specific Gravity at 60° F.	Fat.	Solids, not Fat.	Total Solids.	Relative Dirt Content.	Hours to Curdling.	Total Bacteria.	Acid Bacteria.	Per cent. Acid Bacteria.	Rapid Liquefying Bacteria.	Slow Liquefying Bacteria.	Per cent. Liquefying Bacteria.
September 16,	61	29.1	4.2	8.23	12.43	2	24	449,000	1,250	3	4,660	5,160	2
October 4,	58	30.8	4.4	8.77	13.17	2	37	9,787,500	9,773,750	99	4,680	8,430	0.1
October 11,	—	31.3	4.7	8.93	13.63	4	38	5,433,330	2,487,500	46	21,450	22,290	1
November 4,	59	33.9	4.1	9.46	13.56	1	63	223,330	1,660	0.7	5,830	18,330	11
November 18,	41	31.4	3.8	8.77	12.57	3	65	260,830	47,500	18	15,000	1,660	6
November 22,	45	31.8	4.0	8.94	12.94	2	68	6,205,830	3,171,660	51	21,250	99,000	2
December 9,	37	31.1	4.4	8.77	13.17	3	—	1,000,000	40,000	4	0	7,910	1
Average,	**50**	**31.3**	**4.2**	**8.87**	**13.07**	**2.4**	**49**	**3,337,110**	**2,217,600**	**32.4**	**10,413**	**23,250**	**3.3**

TABLE 49.

Showing Composition of Milk of Producer No. 25.

DATE.	Temperature of Milk.	Specific Gravity at 60° F.	Fat.	Solids, not Fat.	Total Solids.	Relative Dirt Content.	Hours to Curdling.	Total Bacteria.	Acid Bacteria.	Per cent. Acid Bacteria.	Rapid Liquefying Bacteria.	Slow Liquefying Bacteria.	Per cent. Liquefying Bacteria.
September 23, - - -	51	31.0	5.0	8.89	13.89	—	—	51,660	6,450	12	208	830	2
October 4, - - - -	53	30.2	4.5	8.54	13.04	2	48	868,540	60,625	7	625	25,625	3
November 4, - - -	45	30.4	5.8	8.93	14.73	4	48	1,006,000	338,750	38	2,500	66,250	7
November 11, - - -	39	31.2	5.9	9.11	15.01	4	85	100,410	10,830	11	417	2,910	3
December 9, - - -	35	30.4	5.5	9.12	14.62	2	—	1,419,000	330,000	23	69,000	91,500	11
December 20, - - -	37	29.9	5.9	8.80	14.70	3	96	982,500	138,330	14	3,750	136,250	14
December 29, - - -	41	30.1	5.0	8.67	13.67	4	36	6,863,000	2,446,000	36	40,410	533,330	8
January 3, - - - -	43	28.4	5.2	8.29	13.49	4	66	17,593,000	8,206,000	47	9,160	501,660	3
Average, - - -	**43**	**30.2**	**5.4**	**8.74**	**14.14**	**3.3**	**63**	**3,610,000**	**1,442,000**	**23.5**	**15,760**	**169,790**	**6.4**

TABLE 50.

Showing Composition of Milk of Producer No. 26.

DATE.	Temperature of Milk.	Specific Gravity at 60° F.	Fat.	Solids, not Fat.	Total Solids.	Relative Dirt Content.	Hours to Curdling.	Total Bacteria.	Acid Bacteria.	Per cent. Acid Bacteria.	Rapid Liquefying Bacteria.	Slow Liquefying Bacteria.	Per cent. Liquefying Bacteria.
September 19, - - -	73	29.5	—	—	—	3	24	43,776,000	43,666,000	99	0	109,500	0.2
September 27, - - -	66	30.7	—	—	—	3	24	4,209,000	2,460,000	58	3,750	44,790	1
October 28, - - -	47	33.2	4.8	9.40	14.20	4	48	1,072,000	179,160	19	6,660	103,330	10
November 11, - - -	40	31.7	5.0	9.06	14.06	4	85	641,660	61,250	10	7,080	23,750	5
November 15, - - -	49	32.5	4.7	9.21	13.91	5	84	120,410	7,500	6	15,830	3,750	16
November 18, - - -	41	32.9	5.0	9.39	14.39	5	65	27,080	5,830	22	1,660	0	6
November 22, - - -	53	32.1	4.5	9.04	13.54	5	63	6,715,000	6,424,000	96	22,500	21,250	1
December 3, - - -	33	34.1	4.5	9.56	14.06	4	65	384,000	128,000	33	18,500	10,500	8
December 6, - - -	45	33.0	4.5	9.29	13.79	4	72	30,410	12,080	39	0	833	3
January 3, - - - -	35	32.7	4.4	9.20	13.60	4	86	690,830	182,080	26	31,250	42,910	11
February 28, - - -	40	31.7	5.0	9.07	14.07	5	—	91,250	34,160	37	3,330	4,160	8
March 7, - - - -	40	31.7	4.0	8.87	12.87	4	—	162,080	113,750	70	2,080	14,580	10
Average, - - -	**47**	**32.2**	**4.6**	**9.25**	**13.85**	**4**	**62**	**4,826,000**	**4,439,000**	**43.0**	**9,389**	**31,610**	**6.6**

TABLE 51.

Showing Composition of Milk of Producer No. 27.

DATE.	Temperature of Milk.	Specific Gravity at 60° F.	Fat.	Solids, not Fat.	Total Solids.	Relative Dirt Content.	Hours to Curdling.	Total Bacteria.	Acid Bacteria.	Per cent. Acid Bacteria.	Rapid Liquefying Bacteria.	Slow Liquefying Bacteria.	Per cent. Liquefying Bacteria.
September 23, - - -	59	30.9	4.3	8.75	13.05	—	—	727,500	440,000	61	5,830	10,000	2
September 30, - - -	73	30.7	4.5	8.92	13.42	—	32	37,923,000	37,889,000	99	13,330	20,830	1
October 11, - - -	—	—	4.6	—	—	4	34	39,930,000	39,929,000	99	417	208	0
October 28, - - -	51	32.9	5.6	9.46	15.06	3	80	381,660	96,660	25	5,830	20,000	7
November 4, - - -	54	34.2	4.9	9.62	14.52	2	48	2,072,000	1,397,000	67	6,250	62,080	3
November 15, - - -	57	32.6	5.2	9.33	14.53	5	84	655,000	95,000	14	10,000	37,500	7
November 22, - - -	53	34.0	5.0	9.64	14.64	5	72	2,100,000	552,500	26	13,750	40,000	3
December 3, - - -	43	35.5	5.6	10.05	15.65	4	96	1,995,000	398,330	20	10,830	79,160	5
December 9, - - -	50	35.5	5.5	10.11	15.61	2	—	756,250	328,750	43	5,000	23,750	4
December 20, - - -	42	30.1	5.0	8.66	13.66	2	109	1,685,000	932,500	55	2,500	78,330	5
Average, - - -	**54**	**32.9**	**5.0**	**9.46**	**14.46**	**3.4**	**69**	**8,822,000**	**8,206,000**	**50.9**	**7,375**	**37,180**	**3.7**

TABLE 52.

Showing Composition of Milk of Producer No. 28.

DATE.	Temperature of Milk.	Specific Gravity at 60° F.	Fat.	Solids, not Fat.	Total Solids.	Relative Dirt Content.	Hours to Curdling.	Total Bacteria.	Acid Bacteria.	Per cent. Acid Bacteria.	Rapid Liquefying Bacteria.	Slow Liquefying Bacteria.	Per cent. Liquefying Bacteria.
September 16,	53	31.2	5.1	8.91	14.01	5	24	5,923,000	3,024,000	57	8,250	34,250	1
September 27,	59	30.9	—	—	—	4	34	7,565,000	4,675,000	62	10,830	17,700	4
September 30,	66	29.8	5.0	8.64	13.64	—	34	16,645,000	1,380,000	8	46,875	33,430	0.4
October 25,	54	31.3	4.9	8.95	13.85	4	24	—	—	—	—	—	—
November 1,	48	33.4	5.3	9.57	14.87	5	48	1,062,000	14,160	1	14,160	85,830	9
November 18,	41	33.8	4.0	9.44	13.44	4	57	1,787,000	818,750	46	43,750	18,750	3
November 22,	40	33.7	4.0	9.32	13.32	4	61	6,901,000	5,122,000	74	66,660	74,160	2
December 3,	36	34.3	4.8	9.67	14.47	6	60	4,265,000	1,862,000	44	105,000	115,000	5
December 6,	40	33.7	6.0	9.71	15.71	5	64	4,820,000	956,000	20	164,000	246,000	9
December 29,	33	34.0	4.2	9.48	13.68	3	48	58,133,000	55,697,000	91	75,000	164,580	0.4
January 3,	38	32.0	4.7	9.08	13.78	4	80	5,643,000	1,563,000	28	166,660	208,330	7
February 24,	44	33.0	4.2	9.23	13.43	3	—	421,250	398,750	95	416	2,290	0.6
March 3,	52	32.0	4.4	9.02	13.42	4	—	6,308,000	6,254,000	99	14,580	8,330	0.3
March 14,	38	32.5	4.0	8.92	12.92	4	—	487,500	343,330	70	0	5,000	1
Average,	**46**	**33.3**	**4.7**	**9.19**	**13.89**	**4**	**49**	**9,228,000**	**6,316,000**	**53.5**	**55,090**	**77,970**	**3.3**

TABLE 53.

Showing Composition of Milk of Producer No. 29.

DATE.	Temperature of Milk.	Specific Gravity at 60° F.	Fat.	Solids, not Fat.	Total Solids.	Relative Dirt Content.	Hours to Curdling.	Total Bacteria.	Acid Bacteria.	Per cent. Acid Bacteria.	Rapid Liquefying Bacteria.	Slow Liquefying Bacteria.	Per cent. Liquefying Bacteria.
September 19, - - - -	75	28.9	—	—	—	1	24	3,025,000	314,660	10	330	29,750	1
September 27, - - -	66	30.8	—	—	—	2	24	44,890,000	975,000	2	417	34,790	0.1
October 11, - - -	—	—	4.3	—	—	4	34	14,325,000	5,204,000	36	184,370	65,620	2
October 28, - - -	45	29.5	3.9	8.29	12.19	4	48	4,470,000	2,443,000	55	17,500	9,160	1
November 4, - - -	56	32.5	4.5	9.17	13.67	3	60	1,522,000	71,660	5	60,830	206,660	18
November 15, - - -	62	31.3	5.6	9.10	14.70	6	84	404,160	18,330	5	1,660	32,500	8
November 28, - - -	63	27.9	4.8	8.10	12.90	5	62	—	—	—	—	—	—
December 2, - - -	51	30.0	4.6	8.56	13.16	6	72	1,367,000	726,660	53	12,500	44,160	4
December 6, - - -	54	29.3	5.3	8.58	13.88	6	72	115,000	27,500	24	0	5,830	5
December 9, - - -	42	30.1	5.0	8.64	13.64	5	—	31,000,000	30,431,000	98	14,160	20,830	0.1
December 20, - - -	56	30.0	5.4	6.72	12.12	6	65	20,953,000	20,436,000	98	20,830	71,660	0.4
January 3, - - - -	52	31.1	4.7	8.85	13.55	6	70	17,876,000	17,298,000	97	30,000	18,000	0.3
February 24, - - -	51	32.9	3.8	9.13	12.93	6	—	125,000	45,000	36	0	8,330	7
March 3, - - - -	62	30.3	4.1	8.52	12.62	6	—	3,113,000	2,025,000	65	0	26,660	1
Average, - - -	**57**	**30.4**	**4.7**	**8.51**	**13.21**	**5**	**56**	**11,014,370**	**6,155,200**	**45.0**	**26,350**	**44,150**	**3.7**

TABLE 54.

Showing Composition of Milk of Producer No. 30.

DATE.	Temperature of Milk.	Specific Gravity at 60° F.	Fat.	Solids, not Fat.	Total Solids.	Relative Dirt Content.	Hours to Curdling.	Total Bacteria.	Acid Bacteria.	Per cent. Acid Bacteria.	Rapid Liquefying Bacteria.	Slow Liquefying Bacteria.	Per cent. Liquefying Bacteria.
September 16, - - -	59	28.9	4.6	8.31	12.91	6	24	25,053,000	25,045,000	99	1,250	6,500	0
September 27, - - -	58	29.8	—	—	—	5	24	18,000,000	18,000,000	99	0	2,500	0
September 30, - - -	68	30.1	4.7	8.58	13.28	—	32	28,281,000	28,222,000	99	7,500	31,660	0.1
October 4, - - - -	63	30.4	4.9	8.62	13.52	6	40	2,966,000	1,787,000	60	97,910	12,500	4
October 11, - - - -	—	—	5.2	—	—	5	32	88,291,000	86,650,000	98	77,080	102,080	0.2
October 28, - - - -	53	34.0	4.8	9.60	14.40	5	48	2,020,000	500,000	25	58,330	95,830	8
November 4, - - - -	59	31.9	5.0	9.14	14.14	3	48	5,571,000	2,760,000	50	39,160	47,500	2
December 2, - - - -	39	31.7	4.7	9.01	13.71	4	72	1,363,000	421,660	31	36,660	91,660	9
December 6, - - - -	43	32.6	5.0	9.27	14.27	6	72	1,021,000	451,660	44	26,660	30,000	6
Average, - - - -	**55**	**31.2**	**4.9**	**8.85**	**13.75**	**5**	**44**	**19,174,000**	**18,204,000**	**67.0**	**38,280**	**46,690**	**3.3**

The milk in this group also contains a higher average amount of insoluble dirt than does that of any of the preceding groups. The facts shown in these tables are sufficient to portray very clearly the conditions surrounding the production and subsequent handling of this milk. The construction of many of the stables was entirely unsuited for the production of good milk. In many cases there were no windows in the stable for letting in light and no drop behind the cows. The cows themselves were badly covered with filth and the entire surroundings were wholly unfitted for the production of any article intended for human food. As stated earlier in this report the relation between stable conditions and the quality of the milk will be discussed in another report and need not be dwelt upon here.

GENERAL DISCUSSION.

The Total Bacteria.—It is only during the past few years that the question of the wholesomeness of milk has received any consideration on the part of those having in charge the health of the people, except as its wholesomeness might be affected by the use of chemicals in preserving the milk. Now that it is definitely known that some of the most serious of human diseases are sometimes spread by the disease producing organisms being carried in milk attention is being turned to the conditions under which market milk is produced. Thus far most of the bacteriological work with milk has been done by city physicians upon milk after it has reached the city. Much of this milk is shipped long distances and is many hours old when the sample is taken so that the results do not necessarily represent even approximately the bacterial conditions of the milk as it left the producer. The results given in this paper on the contrary represent the bacterial condition of the milk as it was actually delivered each day by the individual producers and the conditions must be due to methods of production and not to changes which have taken place during transportation. What the condition of this milk would be by the time it reached the city and was delivered to the consumer one can only imagine. In fact it was found to be impossible to keep most of this milk sweet long enough to get it to the city even when placed in cars and iced as soon as received. It

was found necessary to pasteurize it before shipping to the city. It was also run through a separator in order to remove a portion of the insoluble filth. If the total bacteria found in these milks be compared with the figures given in the fore part of this article for the bacterial content of market milk as examined in the cities it will be seen that many of these milks were in worse condition when delivered to the shipping station than the average milk is when it reaches the cities. It must not be supposed, however, that the figures given in this paper represent the average quality of Connecticut milk. On the contrary it is probable that they represent about the worst quality, from a sanitary standpoint, of any milk produced in the state. This is due to the fact that the producers are largely foreigners who are unfamiliar with the necessary methods for and ignorant of the importance of producing milk of low dirt and bacterial content. The examination of milk of some other sections shows that many of our dairymen are producing and delivering to the consumers milk which is of excellent quality as determined by the dirt and bacterial content.

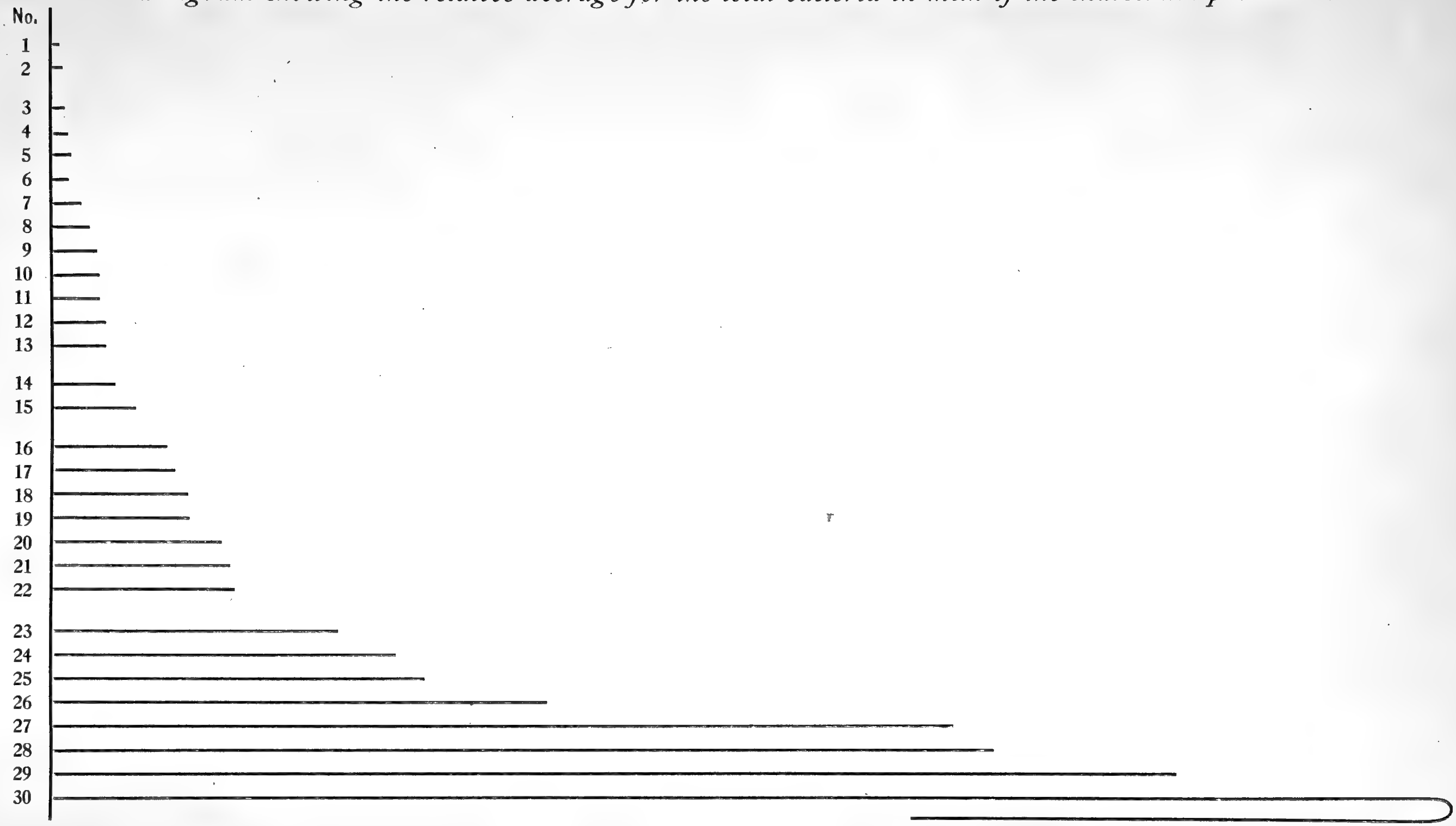
The principal value of the tables in this report lies in the fact that they show the actual daily condition of each man's milk together with the limits between which variations take place. The averages are of far less value than are the individual experiments since they seldom tell more than a part of the truth and in some cases are actually misleading. Yet for those who do not care to study the individual experiments a summary table is inserted here which gives in a condensed form the averages for the foregoing tables. This summary table is followed by a chart showing the relative average bacterial content of the milk from the thirty different producers.

Chemical Composition of the Milk.—As was stated in the early part of this paper the percentage of fat in each sample of milk tested was determined by the Babcock method. The uniformly high fat content of the milk may be easily seen by a study of the various tables while the average for each producer is given in Table 55. Out of the thirty producers whose milk was tested the lowest average for any man is 3.5 per cent. for producer No. 21, and this is considerably above the legal standard as set by the State Experiment Station at

TABLE 55.—*Summary Showing Averages Given in the Preceding Tables.*

Group.	No. of Producer.	Temperature of Milk.	Spec. Gravity at 60° F.	Fat.	Solids, not Fat.	Total Solids.	Relative Dirt Content.	Hours to Curdling.	Total Bacteria.	Acid Bacteria.	Per cent. Acid Bacteria.	Rapid Liquefying Bacteria.	Slow Liquefying Bacteria.	Per cent. Liq. Bacteria.
1	1, - - - - -	50	32.3	4.1	9.02	13.07	4.5	67	61,660	19,740	35.7	2,640	3,780	8.6
	2, - - - - -	48	33.0	4.9	9.42	14.31	2.0	67	81,650	24,640	34.3	1,340	4,417	8.0
2	3, - - - - -	47	32.3	4.4	9.08	13.47	3.0	72	105,820	24,340	33.9	3,330	18,900	13.0
	4, - - - - -	50	31.4	5.6	9.10	14.67	2.6	58	113,270	56,750	26.2	390	1,030	4.7
	5, - - - - -	52	32.3	4.7	9.14	13.87	3.0	68	151,670	56,950	32.3	1,300	2,770	7.9
	6, - - - - -	54	31.2	4.9	8.95	13.83	4.0	66	153,760	64,440	45.9	3,310	12,250	6.7
	7, - - - - -	49	32.1	4.9	9.15	14.10	4.0	81	227,310	36,950	33.8	1,270	18,420	6.7
	8, - - - - -	52	32.5	4.6	9.25	13.83	3.5	53	307,340	56,670	25.1	1,930	20,840	9.3
	9, - - - - -	50	29.9	4.5	8.54	13.04	3.0	68	376,850	111,520	30.5	3,620	10,770	9.9
	10, - - - - -	49	32.8	4.8	9.33	14.11	2.4	70	421,160	4,690	16.5	560	12,070	18.4
	11, - - - - -	48	31.8	4.4	8.90	13.38	4.0	63	426,280	182,810	53.5	1,830	18,330	8.3
	12, - - - - -	58	30.7	5.2	8.67	13.82	5.0	60	473,890	114,090	20.0	95,200	11,660	14.3
	13, - - - - -	49	30.3	4.4	8.56	12.96	3.5	56	488,430	208,800	32.6	9,370	9,030	8.0
3	14, - - - - -	48	33.5	4.6	9.38	13.98	3.4	66	558,610	505,620	58.4	1,830	3,670	4.5
	15, - - - - -	56	30.9	5.2	8.92	14.12	4.0	60	616,610	232,930	18.0	8,025	12,590	11.6
4	16, - - - - -	46	32.6	4.4	9.14	13.54	3.0	65	1,072,180	802,650	36.6	1,655	11,490	4.2
	17, - - - - -	46	33.6	5.4	9.62	15.02	3.0	67	1,153,390	761,440	38.8	3,327	15,880	6.9
	18, - - - - -	47	32.5	4.7	9.18	13.88	3.0	69	1,303,180	1,133,030	35.1	1,872	4,710	3.3
	19, - - - - -	51	31.4	4.4	8.86	13.26	5.0	54	1,303,560	670,850	41.0	5,625	28,630	8.0
	20, - - - - -	48	32.5	5.0	9.22	14.22	2.4	65	1,621,980	840,530	33.5	5,260	9,970	5.9
	21, - - - - -	49	32.1	3.5	8.90	12.40	5.0	55	1,693,730	865,100	43.1	3,920	9,900	2.8
	22, - - - - -	49	31.3	4.4	8.88	13.28	2.0	62	1,773,790	1,453,590	50.5	16,240	40,390	8.5
5	23, - - - - -	46	32.2	4.4	9.18	13.58	3.5	64	2,745,689	2,421,276	48.0	8,268	25,909	5.2
	24, - - - - -	50	31.3	4.2	8.87	13.07	2.4	49	3,337,119	2,217,619	32.4	10,413	23,259	3.3
	25, - - - - -	43	30.2	5.4	8.74	14.14	3.3	63	3,610,708	1,442,291	23.5	15,760	169,797	6.4
	26, - - - - -	47	32.2	4.6	9.25	13.85	4.0	62	4,826,771	4,439,576	43.0	9,389	31,614	6.6
	27, - - - - -	54	32.9	5.0	9.46	14.46	3.4	69	8,822,666	8,206,021	50.9	7,375	37,187	3.7
	28, - - - - -	46	33.3	4.7	9.19	13.89	4.0	49	9,228,019	6,316,224	53.5	55,093	77,975	3.3
	29, - - - - -	57	30.4	4.7	8.51	13.21	5.0	56	11,014,372	6,155,205	45.0	26,356	44,154	3.7
	30, - - - - -	55	31.2	4.9	8.85	13.75	5.0	44	19,174,555	18,204,435	67.0	38,287	46,694	3.3

Diagram showing the relative average for the total bacteria in milk of the individual producers.



New Haven. This is the only producer whose milk averaged below 4 per cent. in fat and seven averaged above 5 per cent. No. 4 being as high as 5.6 for the entire series of tests. In the entire series but four individual tests fell below the standard of 3.25. These all occurred in the milk of one man, producer No. 21, and it will be seen that these figures are in strong contrast to his average test. His other tests were high enough to bring his final average up to 4.9 per cent.

For solids, not fat, the milk of these thirty producers all averaged above the standard of 8.50. More than half of the producers averaged above 9 per cent. for the solids, not fat. In the entire series of experiments but fifteen individual tests fell below the standard. This is, of course, a very small percentage of the entire number of samples tested. The milk of all of these men averaged considerably above the standard of 12 per cent. for total solids, the lowest average being 12.40 for producer No. 21. Only two men had an average below 13 per cent. while eight were above 14 per cent. and one was slightly over 15 per cent. In the entire series only one sample of milk showed a total solids below the standard of 12 per cent. This is an excellent showing for the chemical qualities of this lot of milks.

It is a striking fact that the dirt content increases quite uniformly with the increase of bacteria. This is true if we consider the averages for the different groups of producers, the dirt content increasing quite uniformly with the exception of group 4 which is somewhat below groups 2 and 3. Some of the milk in this group was comparatively clean while the numbers of bacteria ran high. It is evident that the large numbers of bacteria were due in many cases to the temperature at which the milk was kept rather than to contamination through insoluble dirt. In spite of this general relation between the dirt and the number of bacteria there is, however, great lack of uniformity in the tests of any individual producer. At the same time that the bacterial and dirt content increases with the different groups the keeping qualities of the milk uniformly decrease, there being an average difference between the first and fifth groups of ten hours in the keeping quality of the milk. Judged from the chemical standpoint alone all of the milk of these producers must be considered of excellent quality but when the dirt contamination and the numbers of bacteria are taken into account it is apparent that much of this milk is of very inferior quality.

METEOROLOGICAL OBSERVATIONS AT STORRS, AND GENERAL WEATHER AND CROP REVIEW.

REPORTED BY W. A. STOCKING, JR.

For the sixteen years preceding 1904 this Station kept continuous weather records, making observations three times each day in accordance with the directions of the U. S. Weather Bureau. The results of these records have been given each year in the annual report. This work was carried on at a cost of considerable labor and expense on the part of the Station. At the beginning of 1904, after consultation with the New England section of the Weather Bureau, it was deemed advisable to omit a part of the observations formerly recorded by this Station. It has been found by the Weather Bureau that temperature observations taken three times daily are not necessary in order to get a fairly correct idea of temperature conditions. The only data now required by the Weather Bureau of its voluntary observers consists of the daily maximum and minimum temperature readings and a record of the precipitation. This Station has, therefore, during the past year, recorded only the maximum and minimum temperatures each day together with the amount and time of rainfall. For this work the self-registering maximum and minimum thermometers and the rain gauge used by the Weather Bureau are used. This greatly simplifies the matter of taking observations, and, of course, makes it necessary to omit from our annual report certain data that has been previously given.

The mean temperature, together with the maximum and minimum, and the amount and distribution of precipitation are the weather phases which bear most directly upon crop production and agricultural problems in general, and this data is considered of sufficient value to warrant the continuance of this work on the part of the Station. The records now in the

possession of the Station are of considerable value in teaching the subjects of meteorology and climatology, and these records are frequently drawn on for class instruction.

The results of the observations taken at Storrs during 1904 are given in Table 56.

The total precipitation for the year at Storrs was 40.19 inches. This is 8.46 inches less than the total amount for the year 1903, and 7.24 inches less than the average for the past sixteen years. Seven months out of the twelve had a smaller rainfall than the average for the same months during the sixteen years preceding. The principal shortage occurred in May, July and November. This is the smallest total rainfall for any year since 1899, and only three times has it gone below this amount during the sixteen years preceding. The total rainfall for each year since 1888 is given in Table 60. In spite of the large total annual shortage the rainfall was quite uniformly distributed throughout the season, there being no periods of decided drought as in some other years.

The Station has been helped during the growing season by the coöperation of men in different parts of the state who have continued to send us the records of the rainfall for their sections as in previous years. These records, together with a number furnished by the New England section of the Weather Bureau, give quite completely the amount and distribution of rainfall throughout our state. This data is given in Table 57.

In this table are given the amounts of rainfall for the growing season recorded at twenty different places throughout the state. The average of the records taken at these twenty places during the growing season, May to October inclusive, shows the rainfall to be 22.93 inches. The lightest rainfall was at New London where but 17.04 inches was recorded, and the greatest amount was 28.47 inches at Cream Hill. The amount recorded at Storrs was 19.24 inches. This is 2.85 inches less than the rainfall for the same period in 1903, and 1.67 inches less than the average for the past fifteen years.

Table 58 contains a summary of the rainfall for the growing season, May 1 to October 31, as recorded at twenty different places throughout the state for the fifteen seasons preceding that of 1904.

A study of this table shows the fact that the rainfall varied greatly at different parts of the state, frequently being less than half as much at some places as at others. It is also an interesting fact to note that certain sections normally receive a much smaller rainfall than certain other sections. This is especially marked in the case of New London. The average difference between the places receiving the largest and smallest rainfall is 12.38 inches for the fifteen years. The average rainfall, taking the state as a whole, is quite accurately represented by the 24.60 inches given as the average for the last column.

The mean temperature for the year was 44.8°, which is 2.2° lower than the average for the past sixteen years. This is the lowest mean temperature recorded at Storrs since the Station began in 1888. The year which approached most nearly to this was 1893, which had a mean temperature of 45.1°. The unusually low average for the year's temperature was brought about by the severe cold in January, February and March, the means for those three months being 18°, 19° and 34° respectively, while the averages for the past sixteen years for the same months are 25.7°, 25.2° and 36.9°. The extremely cold weather of the winter months was followed by continued cool weather throughout the year, there being only two months when the temperature rose to the normal for those months. May was 0.1° and July 0.6° above the average for the past sixteen years.

In spite of the fact that the season was cool, killing frosts did not occur in the spring later than usual. The dates at different parts of the state varied from April 20 at New Haven to May 3, at which date frost occurred at a number of places throughout the state. The first killing frosts in the fall occurred on September 21 and 22, covering the larger part of the state. New Haven and New London escaped frost until October 27 and 28. At Storrs the last killing frost in the spring occurred April 24, and the first one in the fall came with the general frost of September 22, giving a growing season of 150 days free from frosts. This is three days longer than the average for the preceding sixteen years.

TABLE 56.

Meteorological Observations for 1904.

	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total.	Mean.
Highest temperature, - -	50	49	63	72	83	90	89	83	80	74	59	47	—	70.
Lowest temperature, - - -	—11	—4	3	21	34	41	46	46	29	21	9	—1	—	19.5
Mean temperature, - - -	18	19	34	43	60	63	69	66	60	48	36	22	—	44.8
Total precipitation, inches, -	4.55	2.80	3.31	6.40	1.96	2.53	1.85	6.00	4.71	2.19	1.47	2.42	40.19	—
No. days with .01 inch or more precipitation, - - -	13	8	11	9	6	9	5	7	3	3	2	5	81	—

TABLE 57.

Rainfall during Growing Season, May 1 to October 31, 1904.

Locality.	Observer.	May.	June.	July.	August.	September.	October.	Total in Inches.
		Inches per Month.						
Canton,	G. J. Case,	2.43	3.09	3.55	6.24	6.92	3.38	25.61
Clark's Falls,	E. D. Chapman,	2.89	7.71	1.41	6.61	2.74	—	—
Colchester,	S. P. Willard,	2.74	2.87	2.44	5.07	6.40	2.71	22.23
Cream Hill,	C. L. Gold,	4.28	3.52	6.15	3.89	7.92	2.71	28.47
Falls Village,	M. H. Dean,	4.49	3.78	6.04	2.98	7.44	2.98	27.71
Hartford,	Weather Bureau,	3.19	2.94	3.64	5.45	5.45	2.25	22.92
Hawleyville,	E. N. Hawley,	4.10	2.38	3.63	4.00	7.26	3.69	25.06
Lebanon,	E. A. Hoxie,	3.28	3.08	2.18	5.12	4.00	2.12	19.78
Madison,	J. D. Kelsey,	2.81	2.43	2.07	7.92	4.52	2.21	21.96
New Haven,	Weather Bureau,	2.94	2.46	2.08	6.27	4.96	2.21	20.92
New London,	T. C. Dillon,	2.22	2.14	1.69	4.03	5.00	1.96	17.04
N. Grosvenor Dale,	Grosvenor D. Co.,	1.88	2.20	2.22	6.61	6.72	2.01	21.64
Norwalk,	G. C. Comstock,	1.87	3.19	2.82	8.45	4.46	2.29	23.08
Southington,	L. Andrews,	2.63	2.63	4.85	5.45	6.90	2.55	25.01
South Manchester,	K. B. Loomis,	2.68	2.28	2.30	3.99	4.28	2.09	17.62
Storrs,	Agr. Expt. Station,	1.96	2.53	1.85	6.00	4.71	2.19	19.24
Torrington,	Prof. E. H. Forbes,	3.02	3.62	4.97	5.82	7.11	2.59	27.13
Voluntown,	Rev. E. Dewhurst,	3.30	3.53	1.90	4.31	5.60	1.91	20.55
Waterbury,	N. J. Welton,	3.31	4.20	4.62	4.93	8.02	3.05	28.13
West Simsbury,	S. T. Stockwell,	2.16	2.46	3.47	5.29	5.29	2.90	21.57
Average,	—	**2.91**	**3.15**	**3.19**	**5.42**	**5.79**	**2.52**	**22.93**

TABLE 58.—*Summary of Rainfall for Growing Season, May 1 to October 31, for Twenty Places in Connecticut.*

Year.	Highest.	Place of Occurrence.	Lowest.	Place of Occurrence.	Avg. 20 Observers
1889,	37.38	New Haven,	28.64	N. Woodstock,	32.41
1890,	31.87	Canton,	24.89	New London,	29.07
1891,	23.11	Franklin,	14.91	Waterbury,	19.59
1892,	29.06	Falls Village,	14.12	N. Franklin,	19.67
1893,	28.70	Oxford,	18.31	New London,	24.32
1894,	24.35	New Hartford,	15.69	Lake Konomoc,	19.79
1895,	25.66	Voluntown,	17.01	Newington,	21.63
1896,	26.19	Falls Village,	16.99	New London,	22.30
1897,	39.78	Southington,	23.46	New London,	30.84
1898,	34.88	Voluntown,	23.87	Winchester,	29.54
1899,	25.69	Canton,	15.04	New Haven,	19.34
1900,	31.08	Falls Village,	12.40	New Haven,	19.65
1901,	33.11	Waterbury,	16.20	New London,	27.80
1902,	35.40	Cream Hill,	17.23	New London,	27.21
1903,	34.45	Hawleyville,	16.13	New London,	25.78
Average,	**30.71**	—	**18.33**	—	**24.60**

TABLE 59.

Monthly Mean Temperature for Past 16 Years.

YEAR.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Mean.
1888, - -	—	—	—	—	—	65.3	66.4	67.3	57.1	43.8	39.7	30.0	—
1889, - -	30.8	22.1	34.9	45.6	58.4	65.2	67.9	64.8	59.7	45.8	40.9	35.1	47.6
1890, - -	32.0	31.7	30.8	44.7	54.9	63.3	67.5	66.0	59.5	47.6	37.9	23.4	46.6
1891, - -	28.8	29.3	31.9	46.1	54.1	63.9	65.2	68.4	63.7	48.3	38.2	37.0	47.9
1892, - -	25.5	26.9	29.9	44.9	53.6	67.0	69.2	67.4	59.1	48.5	37.6	25.5	46.3
1893, - -	17.3	23.5	30.3	42.0	54.5	64.2	67.9	68.0	55.9	51.7	38.1	27.8	45.1
1894, - -	27.7	23.0	38.6	44.7	56.4	66.0	70.9	65.8	63.0	50.6	34.1	28.2	47.4
1895, - -	24.4	19.9	31.1	44.1	57.3	66.7	66.1	68.3	63.1	45.0	41.7	32.6	46.7
1896, - -	21.8	26.3	28.5	47.5	59.9	63.2	69.6	68.5	59.9	47.2	43.5	26.8	46.9
1897, - -	25.0	27.0	34.0	46.0	56.0	62.0	69.0	66.0	60.0	51.0	39.0	31.0	47.2
1898, - -	25.0	28.0	40.0	42.0	54.0	64.0	70.0	69.0	63.0	52.0	38.0	29.0	47.8
1899, - -	25.0	22.0	31.0	45.0	56.0	67.0	68.0	67.0	59.0	52.0	39.0	31.0	46.8
1900, - -	27.0	26.0	30.0	46.0	55.0	66.0	71.0	69.0	64.0	54.0	41.0	29.0	48.2
1901, - -	25.0	19.0	33.0	45.0	54.0	67.0	71.0	66.0	62.0	50.0	33.0	29.0	46.2
1902, - -	24.0	25.0	41.0	46.0	55.0	64.0	66.0	66.0	59.0	48.0	44.0	23.0	46.8
1903, - -	26.0	27 8	43.1	45.9	58.8	59.3	68.0	61.7	60.8	51.1	35.8	23.3	46.8
Average, -	**25.7**	**25.2**	**36.9**	**45.0**	**55.9**	**64.6**	**68.4**	**66.8**	**60.6**	**49.2**	**38.8**	**28.9**	**47.0**

TABLE 60.

Monthly Precipitation for the Past 16 Years.

YEAR.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total.
1888, - -	—	—	—	—	—	2.10	1.93	4.97	8.45	6.35	4.94	5.28	—
1889, - -	4.03	1.64	1.96	3.49	2.16	3.50	11.39	3.78	4.00	5.52	5.91	2.88	50.26
1890, - -	2.66	3.28	6.12	3.15	6.33	2.79	2.81	4.26	7.19	5.25	0.82	4.21	48.87
1891, - -	8.52	5.64	4.42	3.51	2.50	1.84	4.96	3.95	4.08	4.14	3.09	4.96	51.61
1892, - -	4.91	1.60	3.00	0.70	5.60	2.77	3.25	5.20	1.40	1.09	5.41	1.35	36.28
1893, - -	2.39	5.88	4.67	3.82	7.12	1.98	1.58	3.79	2.58	6.71	2.45	3.68	46.65
1894, - -	2.24	3.13	1.18	2.67	3.58	0.59	2.09	2.37	3.01	4.16	4.00	4.31	33 33
1895, - -	5.78	0.63	2.62	4.27	2.16	1.78	4.13	3.48	2.97	6.74	6.97	4.12	45.65
1896, - -	1.60	7.10	4.86	0.80	2.72	1.78	3.22	2.71	7.03	3.60	2.49	2.67	40.58
1897, - -	3.84	3.40	3.66	2.37	4.44	2.79	12.24	5.23	1.39	0.92	7.14	5.61	53.03
1898, - -	4.70	4.03	3.09	4.44	3.81	2.48	6.24	5.87	2.22	6.18	6.11	1.96	51.13
1899, - -	3.76	3.97	5.58	2.20	1.17	3.72	5.55	3.27	3.31	1.54	2.10	2.14	38.31
1900, - -	3.42	7.31	6.43	2.67	4.91	4.32	2.76	2.03	2.27	3.21	6.79	2.22	48.64
1901, - -	8.50	1.05	7.18	9.51	6.30	1.96	5.54	7.58	4.33	1.97	3.04	9.55	66.51
1902, - -	2.53	5.11	6.35	3.81	1.73	3.25	7.48	2.17	7.05	5.68	1.10	5.86	52.12
1903, - -	3.73	5.18	7.09	2.81	0.50	9.24	4.56	4.52	1.81	2.79	1.95	4.27	48.45
Average, -	**4.17**	**3.93**	**4.55**	**3.35**	**3.67**	**2.93**	**4.98**	**4.07**	**3.94**	**4.12**	**4.02**	**4.07**	**47.43**

TABLE 61.

Growing Season for past 16 Years.

YEAR.	Last Killing Frost, Spring	First Killing Frost, Fall.	Growing Season.
1888, - - - - - -	May 16	September 7	114 days
1889, - - - - - -	May 4	September 23	142 "
1890, - - - - - -	April 29	September 25	148 "
1891, - - - - - -	May 5	October 17	164 "
1892, - - - - - -	April 30	September 21	144 "
1893, - - - - - -	May 8	October 17	161 "
1894, - - - - - -	May 15	September 26	134 "
1895, - - - - - -	May 17	October 15	150 "
1896, - - - - - -	May 2	September 24	144 "
1897, - - - - - -	April 22	September 28	159 "
1898, - - - - - -	May 10	October 17	160 "
1899, - - - - - -	May 4	September 15	134 "
1900, - - - - - -	May 11	October 18	158 "
1901, - - - - - -	May 6	September 26	142 "
1902, - - - - - -	May 28	October 10	135 "
1903, - - - - - -	May 3	October 15	165 "
Average, - - - -	—	—	147 "

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